

ADVANCES IN
NUMERICAL HEAT TRANSFER

NANOPARTICLE HEAT TRANSFER AND FLUID FLOW

Edited by

W. J. Minkowycz

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J. P. Abraham



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Volume 4

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**ADVANCES IN
NUMERICAL HEAT TRANSFER**

Volume 4

Series in Computational and Physical Processes in Mechanics and Thermal Sciences

Series Editors

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Nanoparticle Heat Transfer and Fluid Flow, *edited by W. J. Minkowycz,
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Advances in Numerical Heat Transfer, Volume 2, *edited by W. J. Minkowycz,
and E. M. Sparrow*

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Preface

The day of nanoparticles and nanofluids has arrived, and the applications of these media are legion. Here, attention is focused on such disparate applications as biomedical, energy conversion, material properties, and fluid flow and heat transfer. The common denominator of the chapters that set forth these applications here is numerical quantification, modeling, simulation, and presentation.

The first chapter of this volume conveys a broad overview of nanofluid applications, while the second chapter presents a critical synthesis of the variants within the thermophysical properties of nanofluids and then narrows the focus to the applications of nanoparticles in the biomedical field. Chapters 3 and 4 deepen the biomedical emphasis. Equally reflective of current technological and societal themes is energy conversion from dispersed forms to more concentrated and utilizable forms, and these issues are treated in Chapters 5 and 6.

Basic to the numerical modeling and simulation of any thermofluid process are material properties. Nanofluid properties have been shown to be less predictable and less repeatable than are those of other media that participate in fluid flow and heat transfer. Property issues for nanofluids are set forth in Chapters 6 and 7.

The last three chapters each focus on a specific topic in nanofluid flow and heat transfer. Chapter 8 deals with filtration. Microchannel heat transfer has been identified as the preferred means for the thermal management of electronic equipment, and the role of nanofluids as a coolant is discussed in Chapter 9. Natural convection is conventionally regarded as a low heat-transfer coefficient form of convective heat transfer. Potential enhancement of natural convection due to nanoparticles is the focus of Chapter 10.

Editors

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Contents

| | |
|---|-----|
| Preface..... | vii |
| Editors..... | ix |
| Contributors | xi |
| Chapter 1 Review of Nanofluid Applications | 1 |
| <i>Kaufui V. Wong and Omar De Leon</i> | |
| Chapter 2 The Role of Nanoparticle Suspensions in Thermo/Fluid and Biomedical Applications | 25 |
| <i>Khalil M. Khanafer and Kambiz Vafai</i> | |
| Chapter 3 Multiscale Simulation of Nanoparticle Transport in Deformable Tissue during an Infusion Process in Hyperthermia Treatments of Cancers..... | 69 |
| <i>Ronghui Ma, Di Su, and Liang Zhu</i> | |
| Chapter 4 Superparamagnetic Iron Oxide Nanoparticle Heating: A Basic Tutorial..... | 97 |
| <i>Michael L. Etheridge, Navid Manuchehrabadi, Rhonda R. Franklin, and John C. Bischof</i> | |
| Chapter 5 Light-Induced Energy Conversion in Liquid Nanoparticle Suspensions..... | 123 |
| <i>Patrick E. Phelan, Robert Taylor, Ronald J. Adrian, Ravi S. Prasher, and Todd P. Otanicar</i> | |
| Chapter 6 Radiative Properties of Micro/Nanoscale Particles in Dispersions for Photothermal Energy Conversion..... | 143 |
| <i>Qunzhi Zhu and Zhuomin M. Zhang</i> | |
| Chapter 7 On the Thermophysical Properties of Suspensions of Highly Anisotropic Nanoparticles with and without Field-Induced Microstructure..... | 175 |
| <i>Jerry W. Shan, Anna S. Cherkasova, Chen Lin, and Corinne S. Baresich</i> | |

Chapter 8 Advances in Fluid Dynamic Modeling of Microfiltration Processes 215
John E. Wentz, Richard E. DeVor, and Shiv G. Kapoor

Chapter 9 Computational Analysis of Enhanced Cooling Performance and Pressure Drop for Nanofluid Flow in Microchannels 249
Clement Kleinstreuer, Jie Li, and Yu Feng

Chapter 10 Natural Convection in Nanofluids 277
Massimo Corcione

Index 319

1 Review of Nanofluid Applications

Kaufui V. Wong and Omar De Leon

CONTENTS

| | | |
|-------|---|----|
| 1.1 | Introduction..... | 1 |
| 1.2 | Heat-Transfer Applications..... | 2 |
| 1.2.1 | Industrial Cooling Applications..... | 2 |
| 1.2.2 | Smart Fluids..... | 3 |
| 1.2.3 | Nuclear Reactors..... | 4 |
| 1.2.4 | Extraction of Geothermal Power and Other Energy Sources | 5 |
| 1.3 | Automotive Applications..... | 6 |
| 1.3.1 | Nanofluid Coolant..... | 6 |
| 1.3.2 | Nanofluids in Fuel..... | 8 |
| 1.3.3 | Brake and Other Vehicular Nanofluids | 8 |
| 1.4 | Electronic Applications..... | 10 |
| 1.4.1 | Cooling of Microchips..... | 10 |
| 1.4.2 | Microscale Fluidic Applications..... | 12 |
| 1.4.3 | Microreactors..... | 13 |
| 1.5 | Biomedical Applications..... | 14 |
| 1.5.1 | Nano-Drug Delivery | 14 |
| 1.5.2 | Cancer Therapeutics | 14 |
| 1.5.3 | Cryopreservation..... | 15 |
| 1.5.4 | Nanocryosurgery..... | 16 |
| 1.5.5 | Sensing and Imaging..... | 16 |
| 1.6 | Other Applications | 17 |
| 1.6.1 | Nanofluid Detergent..... | 17 |
| 1.7 | Nanofluid Patents | 18 |
| 1.8 | Conclusion | 20 |
| | References..... | 21 |

1.1 INTRODUCTION

Nanofluids are dilute liquid suspensions of nanoparticles with at least one of their principal dimensions smaller than 100 nm. From the literature, nanofluids have been found to possess enhanced thermophysical properties such as thermal conductivity, thermal diffusivity, viscosity, and convective heat-transfer coefficients compared with those of base fluids like oil or water [1–6].

From this review, it will be seen that nanofluids clearly display enhanced thermal conductivity, which goes up with increasing volumetric fraction of nanoparticles. The current review does concentrate on this relatively new class of fluids and not on colloids, which are nanofluids because the latter have been used for a long time. Review of experimental studies clearly showed a lack of consistency in the reported results of different research groups regarding thermal properties [7,8]. The effects of several important factors such as particle size and shapes, clustering of particles, temperature of the fluid, and relationship between the surfactant and effective thermal conductivity of nanofluids have not been studied adequately. It is important to conduct more research so as to ascertain the effects of these factors on the thermal conductivity of wide range of nanofluids.

Classical models have not been successful in explaining the observed enhanced thermal conductivity of nanofluids. Recently developed models only include one or two postulated mechanisms of nanofluids heat transfer. For instance, there has not been much fundamental work reported on the determination of the effective thermal diffusivity of nanofluids nor heat-transfer coefficients for nanofluids in natural convection [9].

There is a growth in the use of colloids, which are nanofluids in the biomedical industry for sensing and imaging purposes. This is directly related to the ability to design novel materials at the nanoscale level alongside recent innovations in analytical and imaging technologies for measuring and manipulating nanomaterials. This has led to the fast development of commercial applications, which use a wide variety of manufactured nanoparticles. The production, use, and disposal of manufactured nanoparticles will lead to discharges of nanoparticles to the air, soils, and water systems. Negative effects are likely and quantification and minimization of these effects on environmental health is obligatory. Actual knowledge of concentrations and physico-chemical properties of manufactured nanoparticles under realistic conditions is important to predicting their fate, behavior, and toxicity in the natural aquatic environment. The aquatic colloid and atmospheric ultrafine particle literature both offer evidence as to the presumptive behavior and impacts of manufactured nanoparticles [10], and there is no pretense that a review duplicating similar literature about the use of colloids which are also nanofluids is attempted in the current review, which is an update of Ref. [11].

As they have enhanced properties such as for thermal transfer, nanofluids can be used in a wide range of engineering applications from the automotive industry to the medical arena to applications in power plant cooling systems as well as computers.

1.2 HEAT-TRANSFER APPLICATIONS

1.2.1 INDUSTRIAL COOLING APPLICATIONS

Routbort et al. [12] started a project in 2008 that employed nanofluids for industrial cooling that could result in great energy savings and resulting emissions reductions. For U.S. industry, the replacement of cooling and heating water with nanofluids has the potential to conserve 1 trillion Btu of energy. For the U.S. electric power industry,