Title: Dispersion and Surface Characteristics of Nano-oxide and Carbon Nanotube Suspensions

Abstract:

Over the last few years, nanofluids consisting of nanometer sized particles dispersed in base liquids have been proven to be effective in enhancing the heat transfer characteristics . Nanoparticle suspensions can improve the heat carrying capacity of fluids. This could allow for lower pressure drop, lower coolant pumping power and coolant temperature rise, lower nuclear fuel element temperatures, and lower structural material stresses. Therefore, the potential seems to be enormous in many heat exchanger applications. In order to use these engineered nanofluids in existing air-conditioning/refrigerant systems, nuclear reactors, fundamental understanding of such nanofluid properties is essential, and the jugular issues need to be addressed. The anomalous behavior of the nanofluids in regard to thermal conductivity has been reported in the literature; however, speculation remains as to the cause of this behavior. Brownian motion, loose agglomerates, hydration layer around particles are given as possible mechanisms. Part of this talk will focus on these mechanisms using Brownian dynamics and molecular dynamics. The study of surface chemistry of the nanoparticles, their colloidal suspension and aggregation characteristics will provide information on the mechanisms by which the particles agglomerate, and the effect of the agglomerated particle shape on heat transfer. We consider both nano oxide particles as well as single and double-walled carbon nanotubes, accounting for both hydrophilic and hydrophobic surfaces. Special techniques are proposed with acid treatment and surfactants to ensure complete and long-term dispersion. The extent of oxidation on the wire impacts CHF, and is influenced by the chemical composition of nanofluids in buffer solutions. Overall it is found that for silica suspensions, the burnout heat flux can be increased nearly 3-fold and to even higher heat flux with CNT suspensions.

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Professional Preparation:

University of Madras	Mathematics	B.Sc. (1973)
Madras Institute of Technology	Aeronautical Engineering	B.Tech (1976)
Georgia Institute of Technology	Aerospace Engineering	M.S. (1978)
Univ. of Illinois at Urbana-Champaign	Theoretical and Applied Mechanics	Ph.D. (1983)

Appointments:

- Professor and Chair, Department of Mechanical, Materials and Aerospace Engineering, University of Central Florida, *Jan 2003 – current*
- Advisory Engineer, (*Jan 02 – Jan 03);* Senior Engineer *July 93 – Dec 01*Lockheed Martin)
- Associate Professor, Clemson University, (tenured in 1991) *Aug. 1991 - July 1993*
- Assistant Professor, Clemson University, *Aug. 1985 - Aug. 1991*
- Research Associate/Visiting Assistant Professor (NSF EPSCoR) *Jan. 1983 - Aug. 1985*

Publications (out of over 80):

Journal Publications since 2005:

- Gupta and R. Kumar, **"**Role of Brownian motion on the thermal conductivity enhancement of nanofluids," *Applied Physics Letters*, **91**, 223102, 2007.
- Gupta and R. Kumar, "Three-Dimensional Turbulent Swirling Flow in a Cylinder: Experiments and Computations," *International J Heat and Fluid Flow*, Vol. 28, 249-261, 2007.
- D. Milanova and R. Kumar, "Heat Transfer Behavior of Silica Nanoparticles in Pool Boiling Experiment," *J. Heat Transfer,* in print, February, 2008.
- R. Kumar, A. Sleiti, J. Kapat, "Unsteady Laminar Buoyant Flow Through Rectangular Vents in Large Enclosures," *J. Thermophysics and Heat Transfer,* **20**, No. 2, pp. 276-284, 2006.
- D. Milanova and R. Kumar, "Role of Ions in Pool Boiling Heat Transfer of Pure and Silica Nanofluids," *Applied Physics Letters*, 87, p. 233107, 2005.
- Gupta and R. Kumar, "Lattice Boltzmann Simulation to Study Multiple Bubble Dynamics," submitted to *Int J Heat Mass Transfer*..
- D. Milanova and R. Kumar, "Functionalized Single Walled and Double Walled Carbon Nanotubes for Thermal Enhancement," to be submitted to Nanoletters.
- R. Kumar, "Two-Phase flow microstructures in thin geometries: Multi-field modeling," Ch. 5 in **Heat Transfer and Fluid Flow in Microstructures and Nanostructures**, Eds. Faghri and Sunden, WIT Press, pp. 173-224.

Conference Publications in 2007:

- R. Kumar and D. Milanova, "Dispersion and Surface Characteristics of Nano-oxide and Nanotube Suspensions," **Keynote Lecture**, Interdisciplinary Transport Phenomena, Bansko, Bulgaria, October 14-19, 2007.
- D. Milanova and R. Kumar, "Functionalized Single Walled and Double Walled Carbon Nanotubes for Thermal Enhancement," IMECE, Nov 11-15, Seattle, 2007.
- Gupta and R. Kumar, "Lattice Boltzmann Simulation to Study Multiple Bubble Dynamics," IMECE, Paper #43218, Nov 11-15, Seattle, 2007.
- N. Amini, K. Coffey and R. Kumar, "Experimental and Numerical Study of Dense Layered Nano-Energetic Materials, IMECE, Paper #43670, Nov 11-15, Seattle, 2007.
- D. Joo and R. Kumar, "Experiments in Nucleation Dynamics of High Pressure Refrigerant in Pool Boiling Using Thermo Liquid Crystals," IMECE, Paper #43942, Nov 11-15, Seattle, 2007.
- D. Milanova, R. Kumar, "Colloidal Stability, Dispersion Characteristics, and Ionic Concentration of Nanofluids in Pool Boiling", ICE Nanofluids: Fundamentals and Applications, September 16-20, Copper Mountain, Colorado, 2007.
- K. Talari and R. Kumar, "Liquid Crystal Thermography Studies in Water Pool Boiling at Subatmospheric Pressures,"5th Int. Conf. Nanochannels, Microchannels and Minichannels, Paper ICNMM2007-30193, June 18-20, Puebla, Mexico, 2007.

- D. Milanova and R. Kumar, "Heat Transfer Enhancement in Single-walled and Double-walled Carbon Nanotube Suspensions," NSTI Nanotech2007, Santa Clara, CA, May 20-24, 2007.

Synergistic Activities:

- Leadership Award, Validation and Qualification of the two-phase flow code, Lockheed, 1998
- Commendation for Outstanding Achievement in Two-Phase Flow Experimental and Model Development, Lockheed, 1997
- Byars Prize for Teaching Excellence, College of Engineering, Clemson University, 1986
- Chairman, ASME K-19 Committee, Heat Transfer in Environmental Systems (1997-2000);
  - Vice-Chair (1995-1997); Member since 1985.
- ASME Long Range Planning and Development Committee, Member, 2000-2003.
- ASME Technical Correspondent to Basic Engineering Group (1996 - 1999)
- Reviewer, Research Proposals: NSF, DoE (individual and panel)
- *Reviewer, Technical Articles:*
  J. Heat Transfer , International Journal of Heat and Mass Transfer
  AIAA Journal, Numerical Heat Transfer, Int. J Heat and Fluid Flow
  J. Chemical Eng. Comm., ASME Heat Transfer & Fluids Eng.
  J. Nanoparticle Research, J Engineering Analysis, IEEE J Nanotechnology
- Served in over 25 MS thesis committees including 10 Ph.D. committees as advisor and chairman, and over 30 thesis committees as a member.

- At Lockheed (1993-2002) as Technical Lead, spearheaded a team to develop a next-generation code for coolant flow in microchannels to calculate flow topology and performance with applications in electronic cooling, fuel cells and nuclear industry.

Current Funding

- REU Site: Extension of Knowledge to Small Scale Engineering: Integration, Interface and Interpretation, PI, (co-PI: H. Cho), **National Science Foundation**, May 2007 – May 2010.
- Thermal Modeling and Measurements in Pressurized Boiling, PI, **Knolls Atomic Power Lab**, Sept 2006 – August 2009.
- Research on the use of Hydrogen Sulfide Scavengers in Multiphase Flow, PI, **Petrobras**, Feb 2006 – August 2008.
- Industry/University Cooperative Research Center, Site at UCF in Multiphase Transport Phenomena, PI, (co-PI: P. Jepson), **National Science Foundation**, Sept 2005 – Aug 2008.
- Nanofluid Characteristics in Pool Boiling, PI, (co-PIs: S. Seal, J. Kapat) **National Science Foundation**, Nanotechnology Exploratory Research, July 2004 – Dec 2006.
- Central Florida Space Science Institute, RET, PI, (co-PI: E. Petersen), **National Science Foundation**, May 2004 – May 2007.
- Multiphase Pump Research, PI, **Seepex**, April 2005 – July 2005.
- Thin Film Energetic Materials, PI, (co-PI: K. Coffey) **Lockheed Martin**, April 2005 – Dec 2006.
- Thin Film Energetic Materials, PI, (co-PI: K. Coffey) **High Tech Corridor Council**, April 2005 – Dec 2006.
- Thermochromic Liquid Crystal Measurements in Pressurized Boiling Experiments, PI, **Knolls Atomic Power Laboratory (Lockheed Martin)**, March 2004 – June 2004.
- A Thermal Model to Predict the Temperature Gradient Above an Exothermic Thin Film Thermite Reaction, PI, **Lockheed Martin Missiles and Fire Control**, Sept 2004 – Dec 2004.

f. Collaborators and Other Affiliations:

T.A. Trabold, General Motors; P.F. Vassallo, T.D. Strayer, Knolls Atomic Power Laboratory (KAPL); S. Choi, University of Illinois at Chicago; J.A. Liburdy, Oregon State University; Vish Prasad, Florida International University; Richard Lahey, Donald Drew, G. Ramanath, P. Keblinski, RPI; James Klausner, University of Florida; Ronald Adrian, Arizona State University; Adrian Bejan, Duke University; E.P. Gianellis, U. Wiesner, Cornell University; B. Joseph, U. South Florida; Charles Petty, Andre Benard, Michigan State; George Chase, U Akron; Ram Mohan, U Tulsa.