

A REVIEW ON HEAT TRANSFER ENHANCEMENT STUDIES OF HEAT PIPES USING NANOFLUIDS

G. Kumaresan*, S. Venkateschalapathy

Department of Mechanical Engineering, National Institute of Technology, Tiruchirappalli, Tamilnadu, India, 620015

ABSTRACT

Heat pipe is a special type of heat exchanger that transfers large amount of heat due to the effect of capillary action and phase change heat transfer principle. Recent development in the heat pipe includes high thermal conductivity fluids like nanofluids, sealed inside to extract the maximum heat. This paper reviews, influence of various factors such as heat pipe tilt angle, charged amount of working fluid, nano-particles type, size, and mass/volume fraction and its effect on the improvement of thermal efficiency, heat transfer capacity and reduction in thermal resistance. The nanofluid preparation and the analysis of its thermal characteristics also have been reviewed.

Keywords: heat pipe, nano-fluid, thermal resistance, capillary pressure, tilt angle

1. INTRODUCTION

In the emerging world, the field of electronics is one of the fast developing sciences and its contribution to the technology is rapidly growing day by day. During the end of 20th century, most of the electronic devices were larger in size and they had been adopted with fan or micro fin cooling systems. These cooling methods occupied considerable volume and did not perform effectively whenever heat dissipation is high and this led to high component temperatures, which affect the performance of electronic devices. Due to the advancement in technology, compact devices were developed to dissipate large amount of heat and one such device is a heat pipe. The heat pipes are suitable devices for the cooling purpose and it was first introduced by Gaugler in 1942. Further developments were made by Groover in 1964 at Los Alamos scientific laboratories (Bejan and Kraus, 2003). The design was further modified and some parameters were changed to improve the performance. These are varying the wick structure (Naphon et al., 2009), base fluids (Senthilkumar et al., 2011), inclination angle (Kishorirao et al., 2000; Naphon et al., 2008) operating pressure (Shafahi et al., 2010; Hsuanic et al., 2011), charged amount of working fluid (Lin et al., 2011; Moura et al., 2011), dispersion of nano-particles in the base fluid (Kishorirao et al., 2000; Moura et al., 2011), size of particles (Kang et al., 2006; Wang et al., 2010), kind of nano-particles (Kang et al., 2006; Chen, 2010), mass/volume fraction of nano-particles (Lin et al., 2011; Teng et al., 2009), heat input (Lin et al., 2011; Do et al., 2010) and geometry (Lin and Zhu, 2011) of heat pipe.

2. HEAT PIPE AND ITS LIMITATIONS

A heat pipe contains three different sections; an evaporator at one end, a condenser at other end and an adiabatic section in-between. Figure 1 shows the schematic arrangement of a heat pipe (Knuth and Bohn, 1997). Heat pipe is basically a sealed tube having a wick structure on the inner surface and filled with a fluid at saturated state. Evaporator is the place, where heat is absorbed by the fluid which creates temperature

and thus density difference. In the condenser section, heat is rejected to the surrounding medium. The adiabatic section is externally covered with an insulation layer and it is just acting as a flow passage without any heat losses from the working fluid. The addition and removal of heat in the evaporator and condenser sections respectively, induces a pressure difference thus leading to vapor flow from evaporator to condenser. The liquid is attracted into the evaporator due to the capillary pressure in the wick structure and the process repeats.

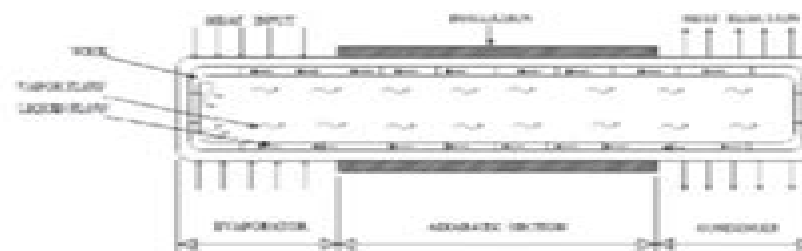


Fig. 1 Heat pipe

The maximum heat transport capacity of a heat pipe is influenced by two limitations; one that leads to heat pipe failure and the other that does not. Limitations that result in heat pipe failure are characterized by insufficient liquid flow to the evaporator for a given heat input, thus resulting in dry out of the evaporator section. The limits categorized under heat pipe failure are capillary limit, boiling limit and entrainment limit. However limitations not resulting in heat pipe failure do require that the heat pipe operate at an increased temperature for an increase in heat input. The three limits are viz. viscous limit, wick limit and

*Corresponding author E-mail: 411111653@nit.edu

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Brian Straughan



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Heat Transfer Enhancement with Nanofluids Vincenzo Bianco,Oronzio Manca,Sergio Nardini,Kambiz Vafai,2015-04-01 Nanofluids are gaining the attention of scientists and researchers around the world This new category of heat transfer medium improves the thermal conductivity of fluid by suspending small solid particles within it and offers the possibility of increased heat transfer in a variety of applications Bringing together expert contributions from Heat Exchangers Sadik Kakaç,Hongtan Liu,Anchasa Pramuanjaroenkij,2012-03-01 Heat exchangers are essential in a wide range of engineering applications including power plants automobiles airplanes process and chemical industries and heating air conditioning and refrigeration systems Revised and updated with new problem sets and examples Heat Exchangers Selection Rating and Thermal Design Third Edition presents a systematic treatment of the various types of heat exchangers focusing on selection thermal hydraulic design and rating Topics discussed include Classification of heat exchangers according to different criteria Basic design methods for sizing and rating of heat exchangers Single phase forced convection correlations in channels Pressure drop and pumping power for heat exchangers and their piping circuit Design solutions for heat exchangers subject to fouling Double pipe heat exchanger design methods Correlations for the design of two phase flow heat exchangers Thermal design methods and processes for shell and tube compact and gasketed plate heat exchangers Thermal design of condensers and evaporators This third edition contains two new chapters Micro Nano Heat Transfer explores the thermal design fundamentals for microscale heat exchangers and the enhancement heat transfer for applications to heat exchanger design with nanofluids It also examines single phase forced convection correlations as well as flow friction factors for microchannel flows for heat transfer and pumping power calculations Polymer Heat Exchangers introduces an alternative design option for applications hindered by the operating limitations of metallic heat exchangers The appendices provide the thermophysical properties of various fluids Each chapter contains examples illustrating thermal design methods and procedures and relevant nomenclature End of chapter problems enable students to test their assimilation of the material

Microscale and Nanoscale Heat Transfer Mourad Rebay,Sadik Kakac,Renato M. Cotta,2016-01-06 Microscale and Nanoscale Heat Transfer Analysis Design and Applications features contributions from prominent researchers in the field of micro and nanoscale heat transfer and associated technologies and offers a complete understanding of thermal transport in nano materials and devices Nanofluids can be used as working fluids in thermal system Nanoparticle Heat Transfer and Fluid Flow W. J. Minkowycz,E Sparrow,J. P. Abraham,2016-04-19 Featuring contributions by leading researchers in the field Nanoparticle Heat Transfer and Fluid Flow explores heat transfer and fluid flow processes in nanomaterials and nanofluids which are becoming increasingly important across the engineering disciplines The book covers a wide range from biomedical and energy conversion applications to mate **Convective Heat Transfer, Third Edition** Sadik Kakac,Yaman Yener,Anchasa Pramuanjaroenkij,2013-12-17 Intended for readers who have taken a basic heat transfer course and have a

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Applications of Nanofluid for Heat Transfer Enhancement Mohsen Sheikholeslami, Davood Domairry Ganji, 2017-02-26 Applications of Nanofluid for Heat Transfer Enhancement explores recent progress in computational fluid dynamic and nonlinear science and its applications to nanofluid flow and heat transfer The opening chapters explain governing equations and then move on to discussions of free and forced convection heat transfers of nanofluids Next the effect of nanofluid in the presence of an electric field magnetic field and thermal radiation are investigated with final sections devoted to nanofluid flow in porous media and application of nanofluid for solidification The models discussed in the book have applications in various fields including mathematics physics information science biology medicine engineering nanotechnology and materials science Presents the latest information on nanofluid free and forced convection heat transfer of nanofluid in the presence of thermal radiation and nanofluid in the presence of an electric field Provides an understanding of the fundamentals in new numerical and analytical methods Includes codes for each modeling method discussed along with advice on how to best apply them

Comprehensive Energy Systems Ibrahim Dincer, 2018-02-07 Comprehensive Energy Systems Seven Volume Set provides a unified source of information covering the entire spectrum of energy one of the most significant issues humanity has to face This comprehensive book describes traditional and novel energy systems from single generation to multi generation also covering theory and applications In addition it also presents high level coverage on energy policies strategies environmental impacts and sustainable development No other published work covers such breadth of topics in similar depth High level sections include Energy Fundamentals Energy Materials Energy Production Energy Conversion and Energy Management Offers the most comprehensive resource available on the topic of energy systems Presents an authoritative resource authored and edited by

leading experts in the field Consolidates information currently scattered in publications from different research fields engineering as well as physics chemistry environmental sciences and economics thus ensuring a common standard and language

Nanofluids and Their Engineering Applications K.R.V. Subramanian,Tubati Nageswara Rao,Avinash Balakrishnan,2019-06-18 Nanofluids are solid liquid composite material consisting of solid nanoparticles suspended in liquid with enhanced thermal properties This book introduces basic fluid mechanics conduction and convection in fluids along with nanomaterials for nanofluids property characterization and outline applications of nanofluids in solar technology machining and other special applications Recent experiments on nanofluids have indicated significant increase in thermal conductivity compared with liquids without nanoparticles or larger particles strong temperature dependence of thermal conductivity and significant increase in critical heat flux in boiling heat transfer all of which are covered in the book Key Features Exclusive title focusing on niche engineering applications of nanofluids Contains high technical content especially in the areas of magnetic nanofluids and dilute oxide based nanofluids Feature examples from research applications such as solar technology and heat pipes Addresses heat transfer and thermodynamic features such as efficiency and work with mathematical rigor Focused in content with precise technical definitions and treatment

Nanofluids and Mass Transfer Mohammad Reza Rahimpour,Mohammad Amin Makarem,Mohammad Reza Kiani,Mohammad Amin Sedghamiz,2021-09-04 In the recent decades efficiency enhancement of refineries and chemical plants has been become a focus of research and development groups Use of nanofluids in absorption regeneration liquid liquid extraction and membrane processes can lead to mass transfer and heat transfer enhancement in processes which results in an increased efficiency in all these processes Nanofluids and Mass Transfer introduces the role of nanofluids in improving mass transfer phenomena and expressing their characteristics and properties The book also covers the theory and modelling procedures in details and finally illustrates various applications of Nanofluids in mass transfer enhancement in various processes such as absorption regeneration liquid liquid extraction and membrane processes and how can nanofluids increase mass transfer in processes Introduces specifications of nanofluids and mechanisms of mass transfer enhancement by nanofluids in various mass transfer processes Discusses mass transfer enhancement in various mass transfer processes such as absorption regeneration liquid liquid extraction and membrane processes Offers modelling mass transfer and flow in nanofluids Challenges industrialization and scale up of nanofluids

Encyclopedia Of Two-phase Heat Transfer And Flow Iv: Modeling Methodologies, Boiling Of Co2, And Micro-two-phase Cooling (A 4-volume Set) John R Thome,2018-05-15 Set IV is a new addition to the previous Sets I II and III It contains 23 invited chapters from international specialists on the topics of numerical modeling of pulsating heat pipes and of slug flows with evaporation lattice Boltzmann modeling of pool boiling fundamentals of boiling in microchannels and microfin tubes CO2 and nanofluids testing and modeling of micro two phase cooling systems for electronics and various special topics flow separation in microfluidics two phase sensors wetting of anisotropic surfaces ultra compact heat

exchangers etc The invited authors are leading university researchers and well known engineers from leading corporate research laboratories ABB IBM Nokia Bell Labs Numerous must read chapters are also included here for the two phase community Set IV constitutes a must have engineering and research reference together with previous Sets I II and III for thermal engineering researchers and practitioners

Applications of Magnetohydrodynamics for Heat Transfer Enhancement Mehdi Fakour,Davood Domiri Ganji,Alireza Ahmadi,2023-06-16 This book is about magnetohydrodynamics explaining how magnetic fields can induce currents within a moving conductive fluid which in turn creates forces on the fluid and influences the magnetic field itself The book explains its governing equations and discusses free forced and mixed convection heat transfers of nanofluids The models discussed in the book have applications in various fields including mathematics physics biology medicine engineering nanotechnology and materials science This book will be of use to professionals researchers scientists policy makers and students with a keen interest within this field This book provides an understanding of the fundamentals of new numerical and analytical methods acting as a remedy for the lack of convenient and integrated sources of information in this specific field of study

Multiphase Flow Handbook Efstathios Michaelides,Clayton T. Crowe,John D. Schwarzkopf,2016-10-26 The Multiphase Flow Handbook Second Edition is a thoroughly updated and reorganized revision of the late Clayton Crowe s work and provides a detailed look at the basic concepts and the wide range of applications in this important area of thermal fluids engineering Revised by the new editors Efstathios E Stathis Michaelides and John D Schwarzkopf the new Second Edition begins with two chapters covering fundamental concepts and methods that pertain to all the types and applications of multiphase flow The remaining chapters cover the applications and engineering systems that are relevant to all the types of multiphase flow and heat transfer The twenty one chapters and several sections of the book include the basic science as well as the contemporary engineering and technological applications of multiphase flow in a comprehensive way that is easy to follow and be understood The editors created a common set of nomenclature that is used throughout the book allowing readers to easily compare fundamental theory with currently developing concepts and applications With contributed chapters from sixty two leading experts around the world the Multiphase Flow Handbook Second Edition is an essential reference for all researchers academics and engineers working with complex thermal and fluid systems

Heat Transfer Enhancement in Plate and Fin Extended Surfaces Sujoy Kumar Saha,Hrishiraj Ranjan,Madhu Sruthi Emani,Anand Kumar Bharti,2019-06-24 This Brief deals with heat transfer and friction in plate and fin extended heat transfer enhancement surfaces It examines Offset Strip Fin OSF Enhancement Principle Analytically Based Models for j and f vs Re Transition from Laminar to Turbulent Region Correlations for j and f vs Re Use of OSF with Liquids Effect of Percent Fin Offset Effect of Burred Edges Louver fin heat transfer and friction correlations flow structure in the louver fin array analytical model for heat transfer and friction convex louver fin wavy fin 3D corrugated fin perforated fin pin fins and wire mesh types of vortex generators metal foam fin plain fin packings

numerical simulation of various types of fins **Nanoparticles in Green Organic Synthesis** Sabyasachi Bhunia, Brajesh Kumar, Pardeep Singh, Ramesh Oraon, Ki-Hyun Kim, 2023-02-23 Nanoparticles in Green Organic Synthesis Strategy towards Sustainability presents the fundamental and latest practical uses of metal nanoparticles MNPs in organic synthesis as well as their promising multidimensional applications The book examines the latest emerging research on MNP synthesis and their applications from organic transformation to energy and the environment allowing readers to critically analyze the role of different MNPs in seeking ideas for widespread application The book covers the fundamentals while also providing a comprehensive account of MNPs and their modification for a variety of green platform based derivatives focusing on the multifunctional technological evolution The book covers a wide range of applications in organic synthesis using a variety of transition metal based nanoparticles in both homo and heterogeneous media The text details the concept of catalyst design and recent developments in the preparation and characterization of nanomaterials followed by several chapters on the design of catalysts for specific applications This volume is a valuable resource for those working in green chemistry sustainability material science and engineering nanotechnology energy and the environment Covers in depth the synthetic routes involved in nanoparticle synthesis in various organic transformations Comprehensively describes the latest technology of MNPs Illuminates key concepts with numerous visual elements such as illustrations or photographs of the featured nanoparticles synthesis schemes spider graphs of strengths and weaknesses of key preparations and synthesis and flow charts and reaction mechanisms

Mechanical and Aerospace Engineering, ICMAE2011 Wu Fan, 2011-10-24 Selected peer reviewed papers from the 2nd International Conference on Mechanical and Aerospace Engineering ICMAE 2011 July 29 31 2011 Bangkok Thailand Heat Waves Brian Straughan, 2011-07-25 This book surveys significant modern contributions to the mathematical theories of generalized heat wave equations The first three chapters form a comprehensive survey of most modern contributions also describing in detail the mathematical properties of each model Acceleration waves and shock waves are the focus in the next two chapters Numerical techniques continuous data dependence and spatial stability of the solution in a cylinder feature prominently among other topics treated in the following two chapters The final two chapters are devoted to a description of selected applications and the corresponding formation of mathematical models Illustrations are taken from a broad range that includes nanofluids porous media thin films nuclear reactors traffic flow biology and medicine all of contemporary active technological importance and interest This book will be of value to applied mathematicians theoretical engineers and other practitioners who wish to know both the theory and its relevance to diverse applications

Vibration and Heat Transfer of Elastic Tube Bundles in Heat Exchangers Jiadong Ji, Baojun Shi, Haishun Deng, 2024-06-23 This book systematically investigates the vibration and enhanced heat transfer of elastic tube bundles in heat exchangers Using numerical calculation methods it explores the working principles optimization design and performance enhancement of elastic tube bundle heat exchangers The book presents research findings with clear illustrations and detailed analysis

allowing readers to gain a deep understanding and practical application of the subject Whether from an academic research or engineering practice perspective this book serves as a valuable reference and guide It provides readers with insight and guidance on both theoretical and practical aspects of the field With its comprehensive coverage and practical approach this book is essential reading for researchers engineers and students interested in the vibration and heat transfer of elastic tube bundles in heat exchangers

Applications of Heat, Mass and Fluid Boundary Layers R. O. Fagbenle, O. M. Amoo, S. Aliu, A. Falana, 2020-01-22 *Applications of Heat Mass and Fluid Boundary Layers* brings together the latest research on boundary layers where there has been remarkable advancements in recent years This book highlights relevant concepts and solutions to energy issues and environmental sustainability by combining fundamental theory on boundary layers with real world industrial applications from among others the thermal nuclear and chemical industries The book's editors and their team of expert contributors discuss many core themes including advanced heat transfer fluids and boundary layer analysis physics of fluid motion and viscous flow thermodynamics and transport phenomena alongside key methods of analysis such as the Merk Chao Fagbenle method This book's multidisciplinary coverage will give engineers scientists researchers and graduate students in the areas of heat mass fluid flow and transfer a thorough understanding of the technicalities methods and applications of boundary layers with a unified approach to energy climate change and a sustainable future Presents up to date research on boundary layers with very practical applications across a diverse mix of industries Includes mathematical analysis to provide detailed explanation and clarity Provides solutions to global energy issues and environmental sustainability

Selected papers of the "1st International Conference on Nanofluids (ICNF)" Patrice Estellé, Leonor Hernandez, Matthias H. Buschmann, 2020-12-10 This Special Issue of *Energies* has emerged as a result of the 1st International Conference on Nanofluids <https://icnf2019.com> which was organized under the auspices of Nanouptake COST Action Overcoming Barriers to Nanofluids Market Uptake <http://www.nanouptake.eu> in Castell Spain in June 2019 The foci of ICNF2019 were the production and the characterisation of nanofluids for different areas of applications in the energy fields namely heat transfer storage of thermal energy boiling and solar systems as well as industrial applications and health and safety issues The first conference edition on this topic gathered more than 200 participants from 45 different countries More than 125 contributions were presented in the nine sections of the congress Some selected authors were invited to send extended versions of their work to the *Energies* ICNF2019 Special Issue After a careful review process nine articles from six different countries were selected for compilation in this Special Issue a total of seven full research papers and two reviews These papers cover a broad range of fundamental and applied research aspects on nanofluid science and development and reflect the current investigations knowledge and challenges encountered in the use of nanofluids for energy applications

Surfactants in Tribology, Volume 5 Girma Biresaw, K.L. Mittal, 2017-09-11 Surfactants play a critical role in Tribology controlling friction wear and lubricant properties such as emulsification demulsification bioresistance oxidation resistance

rust prevention and corrosion resistance This is a critical topic for new materials and devices particularly those built at the nanoscale This newest volume will address tribological properties of cutting fluids lubricant performance related to steel surfaces biolubricants and novel materials and ways to reduce friction and wear Scientists from industrial research and development R D organizations and academic research teams in Asia Europe the Middle East and North America will participate in the work

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