

*Review*

# Review of Developments in Plate Heat Exchanger Heat Transfer Enhancement for Single-Phase Applications in Process Industries

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**Abstract:** A plate heat exchanger (PHE) is a modern, effective type of heat transfer equipment capable of increasing heat recuperation and energy efficiency. For PHEs, enhanced methods of heat transfer intensification can be further applied using the analysis and knowledge already available in the literature. A review of the main developments in the construction and exploration of PHEs and in the methods of heat transfer intensification is presented in this paper with an analysis of the main construction modifications, such as plate-and-frame, brazed and welded PHEs. The differences between these construction modifications and their influences on the thermal and hydraulic performance of PHEs are discussed. Most modern PHEs have plates with inclined corrugations on their surface that create a strong, rigid construction with multiple contact points between the plates. The methods of PHE exploration are mostly experimental studies and/or CFD modelling. The main corrugation parameters influencing PHE performance are the corrugation inclination angle in relation to the main flow direction and the corrugation aspect ratio. Optimisation of these parameters is one way to enhance PHE performance. Other methods of heat transfer enhancement, including improving the form of the plate corrugations, use of nanofluids and active methods, are considered. Future research directions are proposed, such as improving fundamental understanding, developing new corrugation shapes and optimisation methods and area and cost estimations.

**Keywords:** plate heat exchanger; heat transfer; pressure drop; energy efficiency; heat recuperation



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## 1. Introduction

To satisfy the needs of the increasing population on our planet in terms of energy and rising standards of individual comfort, a steady increase in energy demand is inevitable. Even with the contemporary trend for the use of renewable energy sources, the main proportion of energy is generated from the combustion of fossil fuels. With this, significant volumes of greenhouse gases (GHGs) are generated. About 6 Gt CO<sub>2</sub> equivalent was generated during the year 2020 in the United States based on data from the US Environmental Protection Agency [1]. Of that amount, 89.0% was due to fossil fuel combustion in various sectors. The European Environmental Agency [2] reported a similar picture, with 77% of GHG generation in the energy sector and 9% added by the contribution of the industry. To mitigate GHG generation, the plans in the EU include a requirement to enhance the efficiency of energy usage by 32.5% by the year 2030 [2]. One of the measures enabling the fulfilment of these plans is improved recuperation of heat energy, which is possible with the wider use of efficient, compact heat exchangers in which modern methods of heat transfer intensification are implemented [3].

# Modern Developments In Heat Transfer

**Alina Adriana Minea**



## **Modern Developments In Heat Transfer:**

*Modern Developments in Heat Transfer* Warren Ibele, 2012-12-02 *Modern Developments in Heat Transfer* provides information pertinent to heat transfer investigation including convective heat transfer radiation heat transfer as well as heat and mass transfer This book examines the aspects and properties of high temperature heat transfer Organized into 14 chapters this book starts with an overview of noncircular duct heat transfer in a wide range of engineering applications from automobile radiators to nuclear power plants This text then examines the differences between circular and noncircular duct flows Other chapters describe energy transport by radiation wherein photons as energy carriers are released from molecules of the radiating body and travel on straight lines until they are scattered or absorbed by other atoms or molecules This book discusses as well the process of evaporation which results in the conversion of a liquid into a vapor The final chapter deals with plasma dynamics and its features Physicists chemists mathematicians and engineers will find this book extremely useful

*Modern Developments in Heat Transfer* Warren E. Ibele, 1963      **Modern Developments in Gas Dynamics** W. H. Loh, 2012-12-06 During the last decade the rapid growth of knowledge in the field of fluid mechanics and heat transfer has resulted in many significant advances of interest to students engineers and scientists Accordingly a course entitled *Modern Developments in Fluid Mechanics and Heat Transfer* was given at the University of California to present significant recent theoretical and experimental work The course consisted of seven parts I Introduction II Hydraulic Analogy for Gas Dynamics 111 Turbulence and Unsteady Gas Dynamics IV Rarefied and Radiation Gas Dynamics V Biological Fluid Mechanics VI Hypersonic and Plasma Gas Dynamics and VII Heat Transfer in Hypersonic Flows The material presented by the undersigned as course instructor and by various guest lecturers could easily be adapted by other universities for use as a text for a one semester senior or graduate course on the subject Due to the extensive notes developed during the University of California course it was decided to publish the material in three volumes of which the present is the first The succeeding volumes will be entitled *Selected Topics in Fluid and Bio Fluid Mechanics* and *Introduction to Steady and Unsteady Gas Dynamics* Finally I must express a word of appreciation to my wife Irene and to my children Wellington Jr and Victoria who made it possible for me to write and edit this book in the very quiet atmosphere of our home      **MODERN DEVELOPMENTS IN HEAT**

**TRANSFER.** WE Ibele (Ed), 1963      **Modern Developments in Heat Transfer** Massachusetts Institute of Technology, 1960\*      *Advances in Heat Transfer*, 1968 *Advances in Heat Transfer*      **Combustion Technology: Some**

**Modern Developments** Howard Palmer, 2012-12-02 *Combustion Technology Some Modern Developments* reviews modern developments in combustion technology with emphasis on furnace flames Topics covered range from equilibria and chemical kinetics in flames to corrosion and deposits in combustion systems along with combustion aerodynamics and noise Heat transfer from non luminous flames in furnaces is also investigated Comprised of 15 chapters this book begins with an overview of some aspects of the chemistry of flames followed by a discussion on the problem of corrosion and deposits

Subsequent chapters focus on aerodynamics and heat transfer in combustors together with combustion noise and the application of aerodynamic principles to flame stabilization in high speed flow radiative heat transfer in combustion chambers electrical properties of flames flame field interactions and their practical applications generation of electricity by magnetohydrodynamic methods and practical aspects of magnetohydrodynamic power generation The book also assesses the influence of stirred reactor theory on design principles for high performance combustion chambers and concludes with a summary of developments in the design and utilization of oil burners This monograph should be of interest to engineers and combustion technologists

Advances in New Heat Transfer Fluids Alina Adriana Minea, 2017-03-16 Heat transfer enhancement has seen rapid development and widespread use in both conventional and emerging technologies Improvement of heat transfer fluids requires a balance between experimental and numerical work in nanofluids and new refrigerants Recognizing the uncertainties in development of new heat transfer fluids *Advances in New Heat Transfer Fluids From Numerical to Experimental Techniques* contains both theoretical and practical coverage

*Notes for Special Summer Program in Modern Developments in Heat Transfer* Massachusetts Institute of Technology. Special Summer Program in Modern Developments in Heat Transfer, 1962, 1962

*Modern Developments in Energy, Combustion and Spectroscopy* F.A. Williams, A.K. Oppenheim, D.B. Olfe, M. Lapp, 2013-10-22 This compendium of technical articles is dedicated to Professor Stanford Solomon Penner on the occasion of his 70th birthday As one of the most prominent scientists of our times he has been particularly instrumental in advancing the field of combustion science while simultaneously he has developed quantitative spectroscopy into an important engineering discipline and is also a leading international expert on energy issues Written primarily by researchers who were Professor Penner's doctorate students during the last four decades the articles consist of original contributions as well as previously published papers that provide important insights into combustion spectroscopy and energy problems Among the topics included are turbulent combustion flame structure detonations spectroscopic diagnostics spectroscopy of atmospheric gases and physical problems associated with nuclear reactors as well as electric power distribution and energy conversion The book includes a short biography of Professor Penner and a complete bibliography of his publications

**New Developments in Computational Fluid Dynamics** Kozo Fujii, Kazuhiro Nakahashi, Shigeru Obayashi, Satoko Komurasaki, 2006-01-05 Contains 20 papers presented at the Sixth International Nobeyama Workshop on the New Century of Computational Fluid Dynamics Nobeyama Japan April 21-24 2003 These papers cover computational electromagnetics astrophysical topics CFD research and applications in general large eddy simulation mesh generation topics visualization and more

*Recent Developments in Aerodynamics* Arash Shams Taleghani, Farschad Torabi, Mohammad Mehdi Rashidi, 2025-01-24 Aerodynamics is a branch of fluid mechanics that deals with the motion of air and other gaseous fluids and the forces acting on bodies in motion relative to such fluids Aerodynamics are classified according to Mach number into incompressible subsonic compressible subsonic transonic supersonic and hypersonic

aerodynamics Aerodynamics can be divided into different forms of internal or external aerodynamics For example the study of flow properties inside a gas turbine or rocket engine is an example of internal aerodynamics that is important in accurately estimating thrust force Examples of external aerodynamics include the flow around the body of airplanes helicopters space capsules cars rockets and missiles trains ships wind turbines and even such structures as bridges and tall buildings which often have to withstand strong winds Since the first human flights until today aerodynamics has been growing and developing rapidly Aerodynamics is one of the applied sciences in engineering that pursues several goals such as estimating forces moments on objects moving in the air or estimating heat transfer from these objects Aerodynamics investigates how gases interact with moving bodies The main purpose of aerodynamics in most cases is to reduce drag forces and increase lift force which can lead to less fuel consumption in vehicles and achieving the greatest speed Of course in some special cases such as hypersonic aerodynamics there is a greater interest in increasing drag to reduce the adverse effects of aerodynamic heating Another goal of studying aerodynamics is to obtain the details of the flow around flying objects For example the correct operation of a control rudder or flap in a supersonic aircraft or the recognition of the phenomenon of blackout during spacecraft reentry which occurs under the influence of aerothermodynamic heating and plasma formed around the antenna is of great importance

**Introduction to Thermal and Fluid Engineering** Allan D. Kraus, James R. Welty, Abdul Aziz, 2011-09-06 Introduction to Thermal and Fluid Engineering combines coverage of basic thermodynamics fluid mechanics and heat transfer for a one or two term course for a variety of engineering majors The book covers fundamental concepts definitions and models in the context of engineering examples and case studies It carefully explains the methods used to evaluate changes in equilibrium mass energy and other measurable properties most notably temperature It then also discusses techniques used to assess the effects of those changes on large multi component systems in areas ranging from mechanical civil and environmental engineering to electrical and computer technologies Includes a motivational student study guide on CD to promote successful evaluation of energy systems This material helps readers optimize problem solving using practices to determine equilibrium limits and entropy as well as track energy forms and rates of progress for processes in both closed and open thermodynamic systems Presenting a variety of system examples tables and charts to reinforce understanding the book includes coverage of How automobile and aircraft engines work Construction of steam power plants and refrigeration systems Gas and vapor power processes and systems Application of fluid statics buoyancy and stability and the flow of fluids in pipes and machinery Heat transfer and thermal control of electronic components Keeping sight of the difference between system synthesis and analysis this book contains numerous design problems It would be useful for an intensive course geared toward readers who know basic physics and mathematics through ordinary differential equations but might not concentrate on thermal fluids science much further Written by experts in diverse fields ranging from mechanical chemical and electrical engineering to applied mathematics this book is based on the assertion that engineers from all walks

absolutely must understand energy processes and be able to quantify them      *Advances in Numerical Heat Transfer, Volume 3* W. J. Minkowycz, 2009-03-27 Definitive Treatment of the Numerical Simulation of Bioheat Transfer and Fluid Flow Motivated by the upwelling of current interest in subjects critical to human health *Advances in Numerical Heat Transfer Volume 3* presents the latest information on bioheat and biofluid flow Like its predecessors this volume assembles a team of renowned international      **A Review of Some Recent Developments in Hypersonic Flow** Antonio Ferri, 1958      **Cryogenic Heat Transfer** Randall F. Barron, Gregory F. Nellis, 2017-12-19 *Cryogenic Heat Transfer Second Edition* continues to address specific heat transfer problems that occur in the cryogenic temperature range where there are distinct differences from conventional heat transfer problems This updated version examines the use of computer aided design in cryogenic engineering and emphasizes commonly used computer programs to address modern cryogenic heat transfer problems It introduces additional topics in cryogenic heat transfer that include latent heat expressions lumped capacity transient heat transfer thermal stresses Laplace transform solutions oscillating flow heat transfer and computer aided heat exchanger design It also includes new examples and homework problems throughout the book and provides ample references for further study New in the Second Edition Expands on thermal properties at cryogenic temperatures to include latent heats and superfluid helium Develops the material on conduction heat transfer and divides it into four separate chapters to facilitate understanding of the separate features and computational techniques in conduction heat transfer Introduces EES Engineering Equation Solver a computer aided design tool and other computer applications such as Maple Describes special features of heat transfer at cryogenic temperatures such as analysis with variable thermal properties heat transfer in the near critical region Kapitza conductance and network analysis for free molecular heat transfer Includes design procedures for cryogenic heat exchangers *Cryogenic Heat Transfer Second Edition* discusses the unique problems surrounding conduction heat transfer at cryogenic temperatures This second edition incorporates various computational software methods and provides expanded and updated topics concepts and applications throughout The book is designed as a textbook for students interested in thermal problems occurring at cryogenic temperatures and also serves as reference on heat transfer material for practicing cryogenic engineers      **Computational Fluid Dynamics and Heat Transfer** Ryoichi Amano, Bengt Sundén, 2011 Heat transfer and fluid flow issues are of great significance and this state of the art edited book with reference to new and innovative numerical methods will make a contribution for researchers in academia and research organizations as well as industrial scientists and college students The book provides comprehensive chapters on research and developments in emerging topics in computational methods e g the finite volume method finite element method as well as turbulent flow computational methods Fundamentals of the numerical methods comparison of various higher order schemes for convection diffusion terms turbulence modeling the pressure velocity coupling mesh generation and the handling of arbitrary geometries are presented Results from engineering applications are provided Chapters have been co

authored by eminent researchers      **Recent Developments in Automotive Safety Technology** Daniel J Holt, 2004-09-23  
Automotive engineers have been working to improve vehicle safety ever since the first car rolled down some pathway well over 100 years ago Today there are many new technologies being developed that will improve the safety of future vehicles Featuring the 69 best safety related SAE technical papers of 2003 this book provides the most comprehensive information available on current and emerging developments in automotive safety It gives readers a feel for the direction engineers are taking to reduce deaths and injuries of vehicle occupants as well as pedestrians All of the papers selected for this book meet the criteria for inclusion in SAE Transactions the definitive collection of the year's best technical research in automotive engineering technology      **Greenchem: Recent developments in chemical engineering** Mr. Saaket Ajmire, Mr. Nilesh S. Dumore, This event provides a platform for students from all over the country to share latest trends in engineering and technology This event now is eclipsed with silver edge to make it most appreciable Technological Mega Event in our University We are continuously trying for upliftment of talents and innovative ideas of engineering students      Heat Transfer Lectures U.S. Atomic Energy Commission, 1948

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