

*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

**James L. S. Chen, Kambiz Vafai**



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**Modern Developments in Heat Transfer** Warren E. Ibele, 1963      **MODERN DEVELOPMENTS IN HEAT TRANSFER.** WE Ibele (Ed), 1963      *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** Massachusetts Institute of Technology, 1960\*      **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      *Notes for Special Summer Program in Modern Developments in Heat Transfer, Massachusetts Institute of Technology, June 25-July 6, 1962* , 1962      Boiling Heat Transfer R.T. Lahey Jr., 2013-10-22 This volume covers the modern developments in boiling heat transfer and two phase flow and is intended to provide industrial government and academic researchers with state of the art research findings in the area of multiphase flow and heat transfer technology Special attention is given to technology transfer indicating how recent significant results may be used for practical applications The chapters give detailed technical material that will be useful to engineers and scientists who work in the field of multiphase flow and heat transfer The authors of all chapters are members of the CMR at Rensselaer a research centre specializing in the state of the art in multiphase science      Modern Developments in Heat Transfer Massachusetts Institute of Technology. Summer session (1960), 1960      Modern Developments in Heat Transfer , 1956      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      **Modern Developments in Heat Transfer** , 1958      **Modern Development in Heat Transfer** WARREN IBELE, 1963      *Developments in Heat Transfer. Editor, W.M. Rohsenow, Etc. [Lectures Given at the 1964 Course on Modern Developments in Heat Transfer Held at the Massachusetts Institute of Technology.].* Massachusetts Institute of

Technology, Warren Max ROHSENOW, 1964      Modern Developments in Fluid Dynamics Sydney Goldstein, 1965      *Recent Developments of Nanofluids* Rahmat Ellahi, 2018-06 *Recent Developments of Nanofluids*      Thermal Radiation Heat Transfer, Fourth Edition Robert Siegel, 2001-12-07 This extensively revised 4th edition provides an up to date comprehensive single source of information on the important subjects in engineering radiative heat transfer It presents the subject in a progressive manner that is excellent for classroom use or self study and also provides an annotated reference to literature and research in the field The foundations and methods for treating radiative heat transfer are developed in detail and the methods are demonstrated and clarified by solving example problems The examples are especially helpful for self study The treatment of spectral band properties of gases has been made current and the methods are described in detail and illustrated with examples The combination of radiation with conduction and or convection has been given more emphasis nad has been merged with results for radiation alone that serve as a limiting case this increases practicality for energy transfer in translucent solids and fluids A comprehensive catalog of configuration factors on the CD that is included with each book provides over 290 factors in algebraic or graphical form Homework problems with answers are given in each chapter and a detailed and carefully worked solution manual is available for instructors      **Heat Transfer in Food Processing** S. Yanniotis, 2007 Heat Transfer is important in food processing This edited book presents a review of ongoing activities in a broad perspective      Advanced Computational Methods in Heat Transfer IX Bengt Sundén, C. A. Brebbia, 2006 Heat Transfer topics are commonly of a very complex nature Often different mechanisms like heat conduction convection thermal radiation and non linear phenomena such as temperature dependent thermophysical properties and phase changes occur simultaneously New developments in numerical solution methods of partial differential equations and access to high speed efficient and cheap computers have led to dramatic advances during recent years This book publishes papers from the Ninth International Conference on Advanced Computational Methods and Experimental Measurements in Heat and Mass Transfer exploring new approaches to the numerical solutions of heat and mass transfer problems and their experimental measurement Papers encompass a number of topics such as Diffusion and Convection Conduction Natural and Forced Convection Heat and Mass Transfer Interaction Casting Welding Forging and other Processes Heat Exchanges Atmospheric Studies Advances in Computational Methods Modelling and Experiments Micro and Nano Scale Heat and Mass Transfer Energy Systems Energy Balance Studies Thermal Material Characterization Applications in Biology Applications in Ecological Buildings Case Studies      Some Recent Developments in Heat Transfer William Henry McAdams, 1948      Modern Developments in Numerical Simulation of Flow and Heat Transfer James L. S. Chen, Kambiz Vafai, 1992

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