

# Heat, Mass, and Momentum Transfer Analogies for the Fully Developed Turbulent Flow of Power Law Fluids in Circular Tubes

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A new correlation is presented to describe heat and mass transfer at large Prandtl or Schmidt numbers to power law fluids in fully developed turbulent flow in a pipe. The resulting expression for the Stanton number differs from earlier semiempirical correlations in that it is based on a continuous eddy viscosity distribution from the wall to the center of the pipe and contains no adjustable parameters to be determined from heat transfer data. Nusselt numbers determined by the new correlation are in excellent agreement with data on heat transfer to both pseudoplastic and dilatant fluids.

Excellent reviews of the available correlations for heat and mass transfer to inelastic, time-independent, non-Newtonian fluids in fully developed turbulent pipe flow are given by Metzner (18) and Skelland (31). The most widely used correlation to date has been that of Metzner and Friend (19), who extended the theoretical analogy of Reichardt (27) to purely viscous non-Newtonian fluids to obtain the following equation for the Nusselt number:

$$N_{St} = \frac{f/2}{1.20 + c\sqrt{f/2}} N_{Re} N_{Pr} \quad (1)$$

The parameters of the constitutive equation for the non-Newtonian fluid enter Equation (1) through the friction factor  $f$ , the non-Newtonian generalized Reynolds number  $N_{Re}$ , the generalized Prandtl number  $N_{Pr}$ , and the empirical function  $c$ , which in the general case also may be a function of the generalized non-Newtonian Reynolds number. These investigators determined  $c$  empirically from experimental heat transfer coefficients for both pseudoplastic and Newtonian fluids. Their final correlation has the form

$$N_{St} = \frac{f/2}{1.20 + 11.8 \sqrt{f/2} (N_{Pr} - 1) (N_{Pr})^{-1.02}} N_{Re} N_{Pr} \quad (2)$$

The Prandtl number at the wall  $N_{Pr,w}$  is related to the generalized Prandtl number as follows:

$$\frac{N_{Pr}}{N_{Pr,w}} = \left( \frac{16}{N_{Re} f} \right)^{\frac{n-1}{n}} \left( \frac{3n+1}{4n} \right) \quad (3)$$

In developing the above, the rheological behavior of the purely viscous non-Newtonian fluids was represented by the empirical Ostwald-de Waele or power law constitutive

equation

$$\tau = - \left\{ K \left| \sqrt{\frac{1}{2} (\Delta : \Delta)} \right|^{n-1} \right\} \Delta \quad (4)$$

This was chosen in view of its proved ability to portray experimental data over moderately large ranges of shear rate for many systems.

Equation (2) is restricted to nearly isothermal flow. Petersen and Christiansen (25) have extended Metzner and Friend's correlation to nonisothermal and transitional flow. These same authors have argued that the Prandtl number to be used in Equation (2) should be corrected for the fact that the effective viscosity in the wall region is less than that in the turbulent core for pseudoplastic fluids. They suggest that the following effective Prandtl number be used in Equation (2):

$$N_{Pr,e} = \frac{808(n+2)^{0.6+0.01(n-1)}}{1,055(3n+1)} N_{Pr,w} \quad (5)$$

Clapp (4) extended Martinelli's (17) analogy to power law fluids. However, the Nusselt numbers predicted were considerably lower than those he observed for pseudoplastic fluids in the range  $0.7 < n < 0.8$ . He proposed the empirical equation

$$N_{St} = 0.023 (9350)^{0.801-1.07(n-1)} (N_{Re})^{0.67(0.92n)} (N_{Pr})^{0.4} \quad (6)$$

Mizushima and Kuriwaki (30) recently correlated their heat transfer data on both pseudoplastic and dilatant fluids with a modified form of the Chilton-Colburn (3) equation:

$$N_{St} = (0.023)^{0.6n+0.25/(2.05n+1.0)} (N_{Re})^{0.6n+0.25/(2.05n+1.0)} (N_{Pr})^{1/2} \quad (7)$$

Recently, Hughmark (10) has extended Longwell's (15) equation to power law fluids. The mean velocity profile is

# Momentum Transfer In Fluids

**Raffaella Di Napoli**



## **Momentum Transfer In Fluids:**

*Momentum Transfer in Fluids* Wm.H. Corcoran,2012-12-02 Momentum Transfer in Fluids provides information pertinent to fluid mechanics This book discusses several topics related to the movement of fluids including boundary layer analysis statistical treatment of turbulence as well as laminar and turbulent shear flow Comprised of seven chapters this book starts with an overview of the physical nature of momentum and describes the application of this concept to systems of variable weight which are useful in the prediction of the physical behavior of fluids in motion This text then explores the fundamental properties and the macroscopic aspects of turbulent flow Other chapters present the significance and utility of mixing length and other macroscopic turbulence parameters This book discusses as well the prediction of the velocity and friction as functions of position in the flowing stream The final chapter deals with the qualitative aspects of boundary flows for compressible and incompressible fluids This book is a valuable resource for scientists and chemical engineers

**Momentum Transfer in Fluids** William Harrison Corcoran,1956 *Fundamentals of Momentum, Heat, and Mass Transfer* James Welty,Gregory L. Rorrer,David G. Foster,2019-02-20 The field s essential standard for more than three decades Fundamentals of Momentum Heat and Mass Transfer offers a systematic introduction to transport phenomena and rate processes Thorough coverage of central principles helps students build a foundational knowledge base while developing vital analysis and problem solving skills Momentum heat and mass transfer are introduced sequentially for clarity of concept and logical organization of processes while examples of modern applications illustrate real world practices and strengthen student comprehension Designed to keep the focus on concept over content this text uses accessible language and efficient pedagogy to streamline student mastery and facilitate further exploration Abundant examples practice problems and illustrations reinforce basic principles while extensive tables simplify comparisons of the various states of matter Detailed coverage of topics including dimensional analysis viscous flow conduction convection and molecular diffusion provide broadly relevant guidance for undergraduates at the sophomore or junior level with special significance to students of chemical mechanical environmental and biochemical engineering

**Thermofluids** Michael Horsley,Sherwin Keith,1996-12-07 The two associated subjects of thermodynamics and fluid mechanics are combined in this book to provide the reader with an easy to follow text which emphasizes the essential coherence of the material

**A Text Book of Fluid Mechanics and Hydraulic Machines** Bansal,2005-12-30 **Heat, Mass, and Momentum Transfer** Warren M. Rohsenow,Harry Y. Choi,1961 [Fluid Mechanics and Machinery](#) C. P. Kothandaraman,2006 The Text Provides The Following Guidance In Building Of Physical And Mathematical Models Numerical Examples For Each Of The Equations Derived Numbering More Than 100 Sketches And Illustrations Numbering More Than 200 Solved Problems To Highlight Whole Spectrum Of Applications Numbering More Than 400 Objective Questions For Self Evaluation Numbering More Than 700 Graded Problems For Exercise Mostly With Answers Numbering More Than 450 Stress On Validation Of Numerical Results By

Counter Checking Proceedings of the ASME Heat Transfer and Fluids Engineering Divisions American Society of Mechanical Engineers. Heat Transfer Division, American Society of Mechanical Engineers. Fluids Engineering Division, 1995

**Fundamentals of Momentum, Heat and Mass Transfer** James Welty, Charles E. Wicks, Gregory L. Rorrer, Robert E. Wilson, 2007-11-12 Fundamentals of Momentum Heat and Mass Transfer now in its fifth edition continues to provide a unified treatment of momentum transfer fluid mechanics heat transfer and mass transfer This new edition has been updated to include more coverage of modern topics such as biomedical biological applications as well as an added separations topic on membranes Additionally the fifth edition will focus on an explicit problem solving methodology that is thoroughly and consistently implemented throughout the text Designed for undergraduates taking transport phenomena or transfer and rate process courses *Momentum Transfer in Simple Fluids for Viscometric Flows* Stephen Douglas Cramer, 1968

*Computer Modelling of Heat and Fluid Flow in Materials Processing* C.P. Hong, 2019-04-23 The understanding and control of transport phenomena in materials processing play an important role in the improvement of conventional processes and in the development of new techniques Computer modeling of these phenomena can be used effectively for this purpose Although there are several books in the literature covering the analysis of heat tra

**Acid Stimulation Simulation Theory and Application in Carbonate Rocks** Cunqi Jia, Jun Yao, Kamy Sepehrnoori, 2025-04-14 This book provides a theoretical basis and technical support for carbonate acid stimulation design Carbonate reservoirs are one of the most important sources of fossil fuels Acid stimulation is an effective technique for enhancing reservoir performance and boosting production The book stands as a fundamental guide in implementing acid stimulation techniques in carbonate reservoirs It models the acid stimulation process contemplating mass momentum and energy changes alongside the real mineral composition of the carbonate rock matrix Comprehensive sensitivity studies are conducted to elucidate the targeted mechanisms and optimization principles for designing acid stimulation applications in carbonate reservoirs This book also serves as an excellent foundation for numerical simulation providing detailed descriptions of how finite volume methods and sequential decoupling algorithms are utilized for numerical discretization and solving decoupled solutions on staggered grids This book is an essential reference for reservoir engineers academics and students interested in studying and performing acid stimulation in carbonate reservoirs It also helps readers obtain an understanding of modeling reactive flow in porous media with coupling multi physical fields including hydrologic chemical thermal processes and multi scale characteristics In addition this book also delves into scale up methods such as the fundamental theoretical foundations and important theorems of the volume averaging approach The book is used as a textbook for senior undergraduate and graduate courses in petroleum engineering Bioprocess Engineering Principles Pauline M. Doran, 1995-04-03 The emergence and refinement of techniques in molecular biology has changed our perceptions of medicine agriculture and environmental management Scientific breakthroughs in gene expression protein engineering and cell fusion are being translated by a strengthening

biotechnology industry into revolutionary new products and services Many a student has been enticed by the promise of biotechnology and the excitement of being near the cutting edge of scientific advancement However graduates trained in molecular biology and cell manipulation soon realise that these techniques are only part of the picture Reaping the full benefits of biotechnology requires manufacturing capability involving the large scale processing of biological material Increasingly biotechnologists are being employed by companies to work in co operation with chemical engineers to achieve pragmatic commercial goals For many years aspects of biochemistry and molecular genetics have been included in chemical engineering curricula yet there has been little attempt until recently to teach aspects of engineering applicable to process design to biotechnologists This textbook is the first to present the principles of bioprocess engineering in a way that is accessible to biological scientists Other texts on bioprocess engineering currently available assume that the reader already has engineering training On the other hand chemical engineering textbooks do not consider examples from bioprocessing and are written almost exclusively with the petroleum and chemical industries in mind This publication explains process analysis from an engineering point of view but refers exclusively to the treatment of biological systems Over 170 problems and worked examples encompass a wide range of applications including recombinant cells plant and animal cell cultures immobilised catalysts as well as traditional fermentation systems First book to present the principles of bioprocess engineering in a way that is accessible to biological scientists Explains process analysis from an engineering point of view but uses worked examples relating to biological systems Comprehensive single authored 170 problems and worked examples encompass a wide range of applications involving recombinant plant and animal cell cultures immobilized catalysts and traditional fermentation systems 13 chapters organized according to engineering sub disciplines are grouped in four sections Introduction Material and Energy Balances Physical Processes and Reactions and Reactors Each chapter includes a set of problems and exercises for the student key references and a list of suggestions for further reading Includes useful appendices detailing conversion factors physical and chemical property data steam tables mathematical rules and a list of symbols used Suitable for course adoption follows closely curricula used on most bioprocessing and process biotechnology courses at senior undergraduate and graduate levels

**Fundamentals of Biomedical Transport Processes** Gerald E. Miller, 2010 Transport processes represent important life sustaining elements in all humans These include mass transfer processes including gas exchange in the lungs transport across capillaries and alveoli transport across the kidneys and transport across cell membranes These mass transfer processes affect how oxygen and carbon dioxide are exchanged in your bloodstream how metabolic waste products are removed from your blood how nutrients are transported to tissues and how all cells function throughout the body A discussion of kidney dialysis and gas exchange mechanisms is included Another element in biomedical transport processes is that of momentum transport and fluid flow This describes how blood is propelled from the heart and throughout the cardiovascular system how blood elements affect the body including gas

exchange infection control clotting of blood and blood flow resistance which affects cardiac work A discussion of the measurement of the blood resistance to flow viscosity blood flow and pressure is also included A third element in transport processes in the human body is that of heat transfer including heat transfer inside the body towards the periphery as well as heat transfer from the body to the environment A discussion of temperature measurements and body protection in extreme heat conditions is also included Table of Contents Biomedical Mass Transport Biofluid Mechanics and Momentum Transport Biomedical Heat Transport *GATE Life Science Food Science Technology [XL-U] Question Bank Book 3000+ Question Answer* DIWAKAR EDUCATION HUB ,2024-03-01 GATE Life Science Food Science Technology XL U Question Bank 3000 Chapter wise question With Explanations As per Updated Syllabus cover all 04 Chapters Highlights of GATE Life Science Food Science Technology XL U Question Bank 3000 Questions Answer MCQ 750 MCQ of Each Chapter Section Wise As Per the Updated Syllabus Include Most Expected MCQ as per Paper Pattern Exam Pattern All Questions Design by Expert Faculties JRF Holder **Solved Problems In Transport Phenomena: Momentum Transfer** Ismail Tosun,2022-10-04 Transport Phenomena is an umbrella term to describe the fundamental processes of momentum energy and mass transfer This unique compendium covers momentum transfer at the microscopic and macroscopic levels in the three stages of problem solving namely formulation simplification and mathematical solution The book does not overwhelm students with a large repertoire of problems Instead it highlights clear and easy presentation to help students grasp the methodology in problem solving This useful reference text benefits upper undergraduate and graduate level students in the fields of chemical mechanical civil and environmental engineering Related Link s **MOMENTUM TRANSFER IN FLUIDS. BY WILLIAM HARRISON CORCORAN, J. B. OPFELL AND BRUCE HORN BROOK SERGE.** William H. Corcoran,J B. OPFELL,BRUCE H. SERGE,1956 Selected Water Resources Abstracts ,1973 Transport Phenomena in Biomedical Engineering: Artificial organ Design and Development, and Tissue Engineering Kal Renganathan Sharma,2010-07-21 A Cutting Edge Guide to Applying Transport Phenomena Principles to Bioengineering Systems Transport Phenomena in Biomedical Engineering Artificial Order Design and Development and Tissue Engineering explains how to apply the equations of continuity momentum energy and mass to human anatomical systems This authoritative resource presents solutions along with term by term medical significance Worked exercises illustrate the equations derived and detailed case studies highlight real world examples of artificial organ design and human tissue engineering Coverage includes Fundamentals of fluid mechanics and principles of molecular diffusion Osmotic pressure solvent permeability and solute transport Rheology of blood and transport Gas transport Pharmacokinetics Tissue design Bioartificial organ design and immunoisolation Bioheat transport 541 end of chapter exercises and review questions 106 illustrations 1 469 equations derived from first principles *Handbook of Fluids in Motion* Nicholas P. Cheremisinoff,Ramesh Gupta,1983

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