

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:

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

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

$$N_{Nu} = \frac{f/2}{1.20 + 11.8 \sqrt{f/2} (N_{Prw} - 1) (N_{Prw})^{-1/4}} N_{Re} N_{Pr} \quad (2)$$

The Prandtl number at the wall N_{Prw} is related to the generalized Prandtl number as follows:

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

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):

$$N_{Prw} = \frac{808(n+2)^{0.6+0.1/(n-1)}}{1,055(3n+1)} N_{Prw} \quad (5)$$

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

$$N_{Nu} = 0.023 (9350)^{0.821-1/(n+0.9)} (N_{Re})^{0.67/(n+0.9)} (N_{Pr})^{0.4} \quad (6)$$

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:

$$N_{Nu} = (0.023)^{0.6+0.25/(2.06n+1.0)} (N_{Re})^{0.6+0.25/(2.06n+1.0)} (N_{Pr})^{1/3} \quad (7)$$

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

Momentum Transfer In Fluids

Buddhi Prasad Sapkota, PhD



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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* Wm. H. Corcoran,J. B. Opfell,B. H. Sage,1956 **Momentum Transfer in Fluids** William Harrison Corcoran,John B. Opfell,Bruce Hornbrook Sage,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 **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

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