LETTERS TO THE EDITORS-IN-CHIEF

Comment on "The Nakayama-Koyama approach to laminar forced convection heat transfer to power-law fluids," by H. I. Andersson

To the Editors-in-Chief:

I read with great interest Dr. Helge I. Andersson's note[1] in which he carefully examined the accuracy and applicability of our high Prandtl number asymptotic expression for forced convection heat transfer to non-Newtonian power-law fluids.[2] I wish to thank Dr. Andersson for pointing out that the algebraic equation (5) for the momentum shape factor Λ fails to give a realistic solution, when the power-law index n is less than its critical value n_{cr} which, I realize, can be given by

$$n_{cr}=\frac{3m-2+[(3m-2)^2+315m^2]^{1/2}}{21m}$$

It is also gratifying to know that our high Prandtl number asymptote (Eq. (8)) is applicable even for the range $n<n_{cr}$, if exact values are used for the momentum shape factors.

However, I do not agree with Dr. Andersson that our high Prandtl number asymptote (8) is valid only for the cases in which

$$\mathrm{Pr}_x \propto x^{(3m-1)(n-1)/(n+1)} \to \infty \text{ as } x\to 0,$$

corresponding to the range indicated as shaded areas in Figure 4. In what follows, I will show that our high Prandtl number asymptote (8) is valid for all realistic combinations of the power-law index n and the Falkner-Skan parameter m, and hence for most practical problems associated with power-law fluids. According to the low Prandtl number asymptote (12) and the high Prandtl number asymptote (8), the exponent of the apparent Prandtl number Pr_x changes from 1/2 to 1/3, as Pr_x increases. The apparent Prandtl number Pr_{xtr} where two asymptotes intersect each other may be obtained by equating Eqs. (8) and (12), as

$$\mathrm{Pr}_{xtr}=\frac{\left(\dfrac{m}{6nC^{n-1}\Lambda}\right)^{2/(n+1)}\left\{\dfrac{2(2+\Lambda)}{15}\left(1+m-\dfrac{(n-1)(3m-1)}{3(n+1)}\right)\right\}^2}{\left\{\dfrac{3}{10}(1+m)\right\}^3}$$

Thus, the high Prandtl number asymptote can be used when

$$\mathrm{Pr}_x>\mathrm{Pr}_{xtr}$$

or equivalently, when

$$x/L>(x/L)_{tr} \quad \text{for } (n-1)(3m-1)>0$$

and

$$0<x/L<(x/L)_{tr} \quad \text{for } (n-1)(3m-1)<0$$

where

$$(x/L)_{tr}=a^{3/(1-3m)}(\mathrm{Pr}_{xtr}/\mathrm{Pr}_L)^{(n+1)/(n-1)(3m-1)}$$

is the transition point determined by substituting Eqs. (1) and (8) into the foregoing apparent Prandtl number inequality. Furthermore, we note that the characteristic Prandtl number Pr_L is usually quite large,[3] while Pr_{xtr} and a are the order of unity. Thus,

$$(x/L)_{tr}\ll 1 \quad \text{for } (n-1)(3m-1)>0$$

and

$$(x/L)_{tr}\gg 1 \quad \text{for } (n-1)(3m-1)<0$$

Therefore, the inequality $\mathrm{Pr}_x>\mathrm{Pr}_{xtr}$ always holds essentially over the whole heat transfer surface, and so does the high Prandtl number asymptote (8).

Let us estimate $(x/L)_{tr}$ for the case we treated, and discussed by Dr. Andersson in his note, namely, the stagnation flow on a circular cylinder in cross flow. From Eq. (5), we find $\Lambda=0.4911$ for $m=1$ and $n=1.6$, and evaluate

$$\mathrm{Pr}_{xtr}=0.3465$$

which gives, when $a=0.92$,

$$(x/L)_{tr}=7.77\times10^{-4} \text{ (i.e., 0.0445 deg.)} \quad \text{for } \mathrm{Pr}_L=10$$

and

$$(x/L)_{tr}=5.29\times10^{-6} \text{ (i.e., 0.0003 deg.)} \quad \text{for } \mathrm{Pr}_L=100$$

Hence, the high Prandtl number asymptote fails only for a very small stagnation spot, $0\leqslant x/L\leqslant(x/L)_{tr}$, where the boundary layer theory is not applicable anyway. Possible inaccuracy at this stagnation spot (due to the failure of the high Prandtl number assumption at the spot) never affects the overall accuracy of the heat transfer estimate based on our high Prandtl number asymptote (8), since possible upstream errors always tend to diminish downstream due to the parabolic nature of boundary layer flows. Dr. Andersson does not seem to be aware of the foregoing fact.

References

1 Andersson, H. I. The Nakayama-Koyama approach to laminar forced convection heat transfer to power-law fluids. *Int. J. Heat Fluid Flow*, 1988, **9**, 343–346

2 Nakayama, A. and Koyama, H. An asymptotic expression for forced convection in non-Newtonian power-law fluids. *Int. J. Heat Fluid Flow*, 1986, **7**, 99–101

3 Acrivos, A. M., Shah, M. J. and Petersen, E. E. Momentum and heat transfer in laminar boundary layer flows of non-Newtonian fluids past external surfaces. *AIChE J.*, 1960, **6**(2), 312–317

Akira Nakayama, Ph.D.
Associate Professor of Energy and Mechanical Engineering
Shizuoka University, Hamamatsu 432, Japan

Response

To the Editors-in-Chief:

Professor Nakayama's arguments in favor of the high Prandtl number asymptote (8)* is certainly correct for the dilatant

* Equation and reference numbers are as in the Technical Note.

stagnation point flow ($m=1,; n=1.6$) if $Pr=10$ or $Pr=100$. One should, however, be aware of the fact that

$$Nu \sim x^{(3m-n-2)/3(n+1)}$$

i.e., that the Nusselt number defined in Eq. (14a) tends to infinity as the stagnation point $x=0$ is approached. It seems, therefore, more correct to use the low Prandtl number asymptote (12) rather than the high Prandtl number asymptote (8) to provide the stagnation point heat transfer rate at $x=0$ for the space-marching calculation scheme proposed by Nakayama *et al.*[2]

For the moderate Prandtl number case, $Pr=1$, considered for instance by Kim *et al.*,[8] it is readily observed that $(x/L)_{tr}=0.114$ (i.e., 6.53 deg), and the region in which the low Prandtl number asymptote applies is by no means negligible.

Helge I. Andersson
Division of Applied Mechanics
The Norwegian Institute of Technology
N-7034 Trondheim-NTH, Norway

BOOK REVIEWS

Managing steam

Edited by Jason Makansi
New York: Hemisphere Publishing,
224 pp. $37.95 U.S. and Canada

In the first section of this book there is a description of how steam—as well as condensate and hot water—are utilized in various industrial, commercial, institutional, and utility applications. Also included in the first section of the book are chapters on the generation and distribution of steam by various means.

The second section of the book contains chapters on control system theory. General control philosophy is presented initially and this is followed by the various aspects associated with boiler and turbine control systems.

The third, and most extensive, section of the book covers hardware and hardware applications associated with control systems. Valves, valve actuators, steam traps, and flow meters are described in detail. Special valve topics such as noise control, cavitation, high pressure drop, and fire safety are also briefly discussed. In the all-important hardware applications portion, actual control system diagrams are presented showing the proper selection and placement of the control system components.

The fourth and final section of the book provides recommendations for operating, maintaining, and inspecting control system components in order to optimize availability and reliability. The appendix provides ten nomographs for estimating steam properties, pressure drop, orifice sizes, condensation in steam lines, flashing, control valve coefficients, and other valves for special situations.

Leslie Company, a supplier of instruments and controls, had perceived a void in the available literature and the need for a single source devoted to steam management. Thus, it was decided to publish a practical reference book for the practicing engineer involved with steam and energy management. In addition to this limited readership, academicians might find it useful as a resource book on steam generation and control.

Technical information presented in the book has been obtained from a very comprehensive list of references. Information sources included trade journals, technical publications, reference books, and internal corporate documents.

The book is easy to read and presented in a logical order. The diagrams, photographs, and illustrations are clear, legible, and easily understood. The book is essentially error-free.

John R. Stenner

Introduction to nuclear power

By John G. Collier and Geoffrey F. Hewitt
New York: Hemisphere Publishing,
1987. 231 pp. $49.95 U.S. and Canada

This book consists of nine chapters, which are: (1) the earth and nuclear power: sources and resources; (2) how reactors work; (3) cooling reactors; (4) loss of cooling; (5) loss-of-cooling accidents: some examples; (6) postulated severe accidents; (7) cooling during fuel removal and processing; (8) cooling and disposing of the waste; and (9) fusion energy: prospect for the future.

Although the title is *Introduction to Nuclear Power*, this book deals mainly with the thermal aspects of nuclear power. Particular emphases are laid on discussions of real and actual accident scenarios in detail, as well as the problems of fuel removal and disposal of nuclear waste, in order to attain the authors' purpose to dispel current fears in the minds of many people about nuclear power generation through a deeper and more widespread understanding of the technologies and other issues involved. Thus the text is written without unnecessary jargon and with superb illustrations and careful examples and problems; there is a bibliography at the end of each chapter. I think this book is of interest to a variety of readers; the intelligent general reader, the undergraduate or graduate student, and the industrial technologist.

During production of this book, news of the Chernobyl reactor accident in the USSR emerged. Therefore, both material on this reactor type and the information available about the accident at that time are included, but I hope that the whole aspect of accident will be described in detail, as is the TMI-2 reactor incident, in a revised edition in future.

Energy problems are very important at any time and in any place. These are deeply related to global environment. In this sense, this book is useful for people who wish to brief themselves about nuclear power, which is one of the important energy sources.

Itaru Michiyoshi

Exergy analysis of thermal, chemical and metallurgical processes

By J. Szargut, D. R. Morris and F. R. Steward
New York: Hemisphere Publishing,
1988. 332 pp. $59.50 U.S. and Canada

This is the latest monograph on exergy analysis (second-law analysis) and its