Book Review

Perturbation Methods in Heat Transfer, by A. Aziz and T. Y. Na, Hemisphere Publishing Corporation, New York, 1984, 199 pp., $37.50.

Professors Aziz and Na have provided a very useful heat transfer text that will interest students and practioners alike. As its title suggests, the contents focus on the application of perturbation methods to a wide range of heat transfer problems. This limitation is a considerable virture as the book is just under 200 pages in length and moves along at a rapid pace.

Aside from basic concepts, the first chapter introduces a large number of practical heat transfer examples that broadly survey the subject. Most of these examples are solved in the second chapter, which provides a comprehensive treatment of regular perturbation methods; elementary examples such as algebraic or simple ordinary differential equations, are treated first. This exemplary procedure is maintained in the subsequent chapters.

The third chapter introduces the concept and reasons for singular perturbation procedures. Chapters four and five treat this type of problem with the method of strained coordinates and matched asymptotic expansions, respectively. Unfortunately, the treatment of matched asymptotic expansions is too perfunctory. The systematic method for determining the gauge functions of the inner and outer expansions is not explained. The reader is thus unaware of the occasional necessity, for example, of terms of order $\epsilon\ell n\epsilon$. Methods for forming a uniformly valid composite expansion are also not treated. The last chapter is a brief presentation of the series extension method, locating and moving of singularities, and related topics.

On the whole, the book admirably fills a large void in the heat transfer literature. It is, however, seriously marred by an inordinate number of errors that occur throughout the text. For instance, the two references I checked were both in error. In section 3.6, θ is referred to as the average temperature, whereas θ/ℓ is the average temperature. Freezing in a finite slab, section 5.4, is first formulated in terms of two independent and two dependent variables. The subsequent nondimensional formulation, however, involves three independent and three dependent variables. This abrupt change is made without any discussion or explanation.

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Laminar-Turbulent Transition, V. V. Kozlov, Editor, Springer-Verlag, New York, 1985, 795 pp., $85.00.

The five-day Second Symposium on Laminar-Turbulent Transition of the International Union of Theoretical and Applied Mechanics was held in July 1984 just outside of Novosibirsk in the Akademgorodok (Academic City, a Siberian concentration of research institutes of the Soviet Academy of Sciences) located in the center of Siberia. It was attended by 140 scientists and engineers from fourteen countries, including 14 from the United States, 10 from Japan, 85 from the Soviet Union, and 14 from other Eastern countries. The all-English proceedings contain 95 papers, including 11 twelve-page invited lectures and 33 six-page poster papers. The 759-page volume covers instabilities and transition in boundary layers (some with separation interaction), channels and pipes, free shear layers, flows between rotating shells, and even relaminarization in supersonic expansions. There are 11 predominantly Soviet papers on supersonic problems, and 4 papers involve gravity-conditioned systems. The approach is theoretical in 44 papers, experimental in 33, and combined in 5; moreover, 8 papers describe numerical experiments and 5 involve engineering correlations of experimental data.

The Symposium was organized primarily by a nucleus of experts from the Institute for Theoretical and Applied Mechanics in Novosibirsk to demonstrate Soviet progress in the stability and transition field. The 57 Soviet contributions indeed represent a unique snapshot of the Russian theoretical and experimental (!) effort *in English*. The quality ranges from excellent to poor and irrelevant, as does the quality of the non-Soviet papers. In view of the variability of quality and the wide range of topics, some perspective and guidance, albeit subjective, are in order.

Advances in data acquisition and processing and in computing have opened new experimental and theoretical vistas in this field of uncertainties. Practical utilization of linear-stability codes in design beckons. In flat-plate and mixing-layer flows, the extra capabilities have already pushed our understanding to secondary and tertiary instabilities. (For recent readable expositions and correlations see Ref. 1. Somewhat earlier comprehensive experimental and theoretical overviews are available in two Russian books.[2,3]) The number of higher-order nonlinear flow solutions in response to the multiple parameters of disturbance environments is immense. Unfortunately, some papers essentially present computational consequences of a series of assumptions and see agreement in qualitative behavior of gross measurements. Validation of theoretical insights can come only from judicious choices of parameters and quantitative *detailed* agreement between theoretical results, numerical experiments, and clean physical experiments. Such convincing mutual (international) support is evident concerning the Herbert secondary subharmonic instability in the papers by Herbert, Nishioka et al., Kleiser-Laurien, Kachanov-Levchenko,[4] and to a lesser extent Maslennikova-Zelman and Ramazanov. The older, higher-order instabilities studied by Klebanoff and coworkers are rechecked in the paper by Kachanov, Kozlov, Levchenko and Ramazanov. The disagreement is one of interpretation: since Klebanoff's higher-frequency spike formations are grafted onto a *moving* fundamental wave, the spectra show only strong growth of its higher harmonics and not the spike frequency. KKLR then view this harmonic growth as "purely deterministic" and not a hairpin-producing instability. However, hydrogen-bubble visualization and hot-wire traces by Matsui-Okude on pp. 628-629 leave little doubt that spikes correspond to newborn smaller-scale hairpin eddies.

There is heartening agreement in papers by Mack and by Kachanov on hole-excited monochromatic fields. This buttresses the development of linear three-dimensional theory, although non-parallelism of the boundary layer presents some problems. On the other hand, the linear three-dimensional code of Malik-Poll predicts highly amplified waves progressing at an angle to the local stream direction on swept-back wings. Yet Michel, Arnal, Coustols, and Juillen and Saric-Yeats find the steady, nearly streamwise vortices as the dominant first mode. This blatant discrepancy with practical consequences calls for resolution. Both could be correct if the supply of streamwise vorticity disturbances in the free stream and on the wing via distributed roughness was substantially stronger than that of the unsteady skew waves near the dangerous frequency. The race also depends on the vorticity patterns actually imprinted on the boundary layer by the environment—the specific receptivity of the layer to the unstable modes. The higher-order instabilities of these streamwise vortices and those of Görtler are just beginning to be explored; see papers by Reed and by Aihara et al.

The Soviets have also been active in receptivity; see the critical overview[5] (in English) of Soviet and American experiments. For extra thin flat plates Kosorygin, Levchenko and Polyakov demonstrate that both their "natural" environment and a downstream loudspeaker seed dangerous frequencies just past the leading edge, evidently as a result of an unsteady antisymmetric pressure field at the lip. Two surprises: *very slow* decay to the neutral point (further but weaker receptivity seeding?) and a third unexplained fluctuating velocity maximum near the wall after large amplification in the unstable region. The experiments of Leehey, Gedney and Her agree that ultimately growing waves can be generated by vibrations of thin leading edges as well as by acoustic excitation, and that they superpose linearly (negatively when out of phase) but see no extra velocity maximum. A more practical receptivity to sound than that of the rather singular leading edge has been analyzed by Ruban. Very small protuberances and changes of curvature of the wall generate surprisingly efficiently amplifiable vorticity waves when irradiated by grazing sound waves. His analysis via triple-deck structure for the unsteady field matches that of Goldstein.[6] Still another practical acoustic receptivity path is documented in Ref. 5.

An important experiment by Gilev documents for the first time receptivity and generation of vorticity waves by local vibrations of the wall away from the leading edge. This nonhomogeneous Orr-Sommerfeld problem was solved by Tumin and Fedorov and by Terentiev (again by triple-deck theory). The two methods should be translatable into practical computer codes.

Zanin's hot-wire studies on a glider in a wind tunnel and in flight (inside and away from clouds) showed that in all three cases the road to turbulence passed through Tollmien-Schlichting-Schubauer amplification despite the vastly different environmental spectra. The experimental paper by Lysenko and Maslov on supersonic cooling illustrates effects on three disturbance modes and explains rationally the infamous transition reversal and rereversal with cooling. Unfortunately, all Russian supersonic theory is locked on to the definitely inadequate Dunn-Lin approximate stability equations, so that comparison with their theory is thwarted. The experimental paper of Aihara, Tomita and Ito on Görtler vortices is of special interest because of Hall's criticism of the separability assumption,[7] which put the linear stability graphs into limbo.

Finally, comments on free shear layers. Zhang, Ho, and Monkewitz compare theoretical and experimental interaction of the fundamental and its subharmonic in a two-velocity mixing layer as a function of the phase angle between them. Low-frequency difference modes between frequencies f_1 and f_2 excited in a slender wake are studied by Miksad, Jones and Powers, especially their role in downstream randomization. Perturbations of Stuart's inviscid finite-amplitude vortices in a mixing layer and some weakly nonlinear modeling of interactions serve as tools for Rabinovich and Suchchik to study the evolution of the flow toward chaos. They also interpret external excitation as modifying the road toward the strange attractor as well as the attractor type itself. Experimental studies of attractor evolution were made for a cylindrical Couette flow by Lukaschuk et al., and for a spherical Couette flow by Belayev et al.

Many of the other papers are not easy to read. Some authors merely condense a number of their recent references; misprints, the frequently poor English and inadequate symbol definitions make it even more difficult to understand the claims. For $85 per photo-offset copy, Springer should have provided for an editor of English.

On the other hand, the volume overviews much material not readily available elsewhere. It also testifies to much progress since the 1980 volume on the First Symposium (same title and publisher, R. Eppler and H. Fasel, editors).

[1] *Special Course on Stability and Transition of Laminar Flow*, AGARD Rept. 709, 1984, pp. 220.

[2] Kachanov, Yu. S., Kozlov, V. V., and Levchenko, V. Ya., *Genesis of Turbulence in Boundary Layers* (in Russian), Nauka, Novosibirsk, 1982.

[3] Gaponov, S. A. and Maslov, A. A., *Disturbance Propagation in Compressible Flows* (in Russian), Nauka, Novosibirski, 1980.

[4] Kachanov, Yu. S. and Levchenko, V. Ya., "The Resonant Interaction of Disturbances in Laminar-Turbulent Transition in a Boundary Layer," *Journal of Fluid Mechanics*, Vol. 138, 1984, pp. 209-247.

[5] Nishioka, M. and Morkovin, M. V., "Boundary-Layer Receptivity to Unsteady Pressure Gradients: Experiments and Review," accepted by the *Journal of Fluid Mechanics*.

[6] Goldstein, M. E., "Scattering of Acoustic Waves into Tollmien-Schlichting Waves by Small Streamwise Variations in Surface Geometry," *Journal of Fluid Mechanics*, Vol. 154, 1985, pp. 509-529.

[7] Hall, P., "The Linear Development of Görtler Vortices in Growing Boundary Layers," *Journal of Fluid Mechanics*, Vol. 130, 1983, pp. 41-58.

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