Book reviews

Stability of Parallel Gas Flows

B. K. Shivamoggi

Stability, in fluid mechanics, is concerned with the mechanism of the breakdown of laminar flow and the consequent transition to turbulence. An analytical investigation, superimposing a hydrodynamically possible disturbance on a basic steady flow, requires the solution of a system of non-linear partial differential equations which is, in general, far too formidable a task. Stability theory circumvents this problem by linearizing the equations and assuming a travelling wave solution containing an exponential time factor, $\exp(i\alpha(x-ct))$. For homogeneous boundary conditions this leads to a characteristic value problem in ordinary differential equation theory with the phase velocity, c, of the disturbance as a parameter. An oscillatory mode is now said to be stable, neutral or unstable depending upon whether the imaginary part of αc is negative, zero or positive. The characteristic value, c, may be obtained by asymptotic or numerical methods. The results of the theory show that the stability is dependent upon the Reynolds number and this has been experimentally verified.

The first two chapters of Shivamoggi's book reviews and extends this basis stability theory for incompressible flows. For inviscid incompressible flow it is shown that the characteristic value problem reduces to the solution of Rayleigh's equation which is then used to obtain not only the established but also some quite recent results on the necessary and sufficient conditions for the existence of unstable and neutral modes of oscillation. The inclusion of viscosity requires the solution of the Orr-Sommerfeld equation, and here asymptotic methods are used to obtain the neutral-stability curve which shows that the stability is dependent upon the Reynolds number.

Chapters three to seven discuss the solution of inviscid compressible flow problems with much of the work being taken from Shivamoggi's own research in this field. The author demonstrates that Squire's theorem for incompressible flow, which states that every three-dimensional problem may be treated in terms of an equivalent two-dimensional problem, no longer holds. Ideally it is therefore necessary to consider a full three-dimensional theory but, to make progress, the theoretical presentation here has been restricted to two-dimensional flow along with some other simplifying approximations. After the usual linearization it is shown, once again, that a characteristic value ordinary differential equation can be obtained, this time for inviscid compressible flow. Travelling wave solutions of this equation are now classifed as subsonic, sonic or supersonic depending upon whether the phase velocity in the direction of the mean flow and relative to an observer moving with the velocity of the mean flow is below, equal to or above the local speed of sound in magnitude. For subsonic flow it is shown that it is possible to obtain necessary and sufficient conditions for instability corresponding to the conditions for inviscid incompressible flow given earlier. However it does not appear to be possible to obtain any similar results for supersonic flow. Further a comparison of subsonic with supersonic flow through a phase plane analysis shows that whereas a given basic flow executes a unique set of subsonic oscillations, no uniqueness exists in the execution of supersonic oscillations. Also included is an investigation of the stability of the surface waves generated in a liquid adjacent to a high speed gas stream, where it is shown that the manner of energy transfer from the gas stream to the surface waves is dependent upon whether the flow is subsonic or supersonic. The final two chapters of the book discuss viscous compressible flow. Here asymptotic series methods are used to obtain solutions to the free shear and boundary layer problems, the results being used to discuss the general character of the neutral stability curves.

As the above brief outline shows, the book is largely analytical and consequently rather narrow in its range. Thus there is little or no mention of the numerical methods available for the solution of the eigenvalue problem which give a viable alternative to the analytical methods considered here. Neither is there any comparison between theoretical and experimental results. These limitations, however, in no way detract from the value of the book, which provides new theoretical insights into the stability of compressible flows, and is a useful addition to the literature on hydrodynamic stability.

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Turbulence and Random Processes in Fluid Mechanics

M. T. Landahl and E. Mollo-Christiansen

This short book is based on the authors' lecture notes at MIT, and shows both the strengths and the weaknesses of its origin. The authors give an illuminating and thought-provoking treatment of a wide variety of topics, including waves, transition, noise and buoyant convection, in addition to turbulence as such. Inevitably, therefore, the discussion is somewhat lacking in detail for readers who have not attended the prerequisite courses. Unexplained background is not a serious drawback—a graduate student who does not know what a Lagrangian wave function or a quadrupole is can probably find out—but missing definitions and missing steps in arguments are irritating or confusing to a reader who cannot question the lecturer. Small but typical examples are a reference to Rayleigh's proof than an inflexion point is a necessary condition for instability, sited sufficiently far from the statement that Rayleigh's work referred only to inviscid fluids that a student may take it as a general result; a proof of the symmetry of autocorrelations which is stated to involve a shift of time origin by *twice* the time delay τ bur which in fact requires a shift equal to τ followed by commutation; and a confusing miscellany of values for the logarithmic law constants without a clear indication that the differences are within experimental scatter.

The section on turbulence modelling and large-eddy simulation is so cursory as to be virtually useless. For the expert, though, the book has many delights. This reviewer's favourite section is one called 'How little a spectral density tells about a signal' which makes its point with gentle wit and a neat example; there is a helpful special-case proof of the central limit theorem, using the book's brief but clear exposition of statistical tools; the forbidding six-fold integral of a quadruple correlation that gives the density autocovariance in aerodynamic noise theory is cut down to the U^8 law in six lines and two equations.

In summary, this small book is like aquavit; stimulating and cheering, but not to be given undiluted to young persons.

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