

Preface

Overview

The origin of turbulence in fluids is a long-standing problem that has been the focus of research for decades due to its great importance in a variety of engineering applications. Moreover, studying of onset of turbulence is part of the fundamental physical problem of turbulence description and the philosophical problem of determinism and chaos.

In the present book we try to give a panoramic view of the transition of turbulence in near-wall shear flows by binding its different aspects for incompressible flows according to our knowledge obtained during decades of researches. To be in line with this general idea, there was a need to pick out the material for inclusion from plenty of available sources. In this way, our priority was a conceptual treatment of various both classical and modern aspects of the problems under consideration.

The scope and the resulting structure of the book were chosen based on experience collected owing to one semester lecture courses for PhD students read by some of us at Novosibirsk State University, Korean Advanced Institute of Science and Technology, and Pusan National University.

Thus, the book is intended first of all for beginners in this field of science. We expect that the result of our efforts will also be of interest to researchers and high-school teachers involved in hydro-aerodynamics, stability, and laminar–turbulent transition problems.

Prerequisites

Readers of this book are expected to be familiar with the concepts of fluid mechanics of viscous incompressible flow and Prandtl boundary-layer theory. It is also desirable, but not required, for the reader to know basic ideas of linear algebra and to have some experience with matrix computations and MATLAB programming.

Organization of the Book

In Chaps. 1 and 2, we begin with basic observations and the fundamentals of the classical stability theory, which describes low-intensity shear-layer perturbations as instability waves.

Chapters 3–7 are devoted to various generic problems of the theory to show how different isolated factors such as curvature, pressure gradients, flow separation, etc. affect the linear stability of shear flows. The palette of these factors certainly is not exhaustive. However, the set is diverse enough to provide a general view of the basic aspects of the stability analysis.

In Chaps. 8–11, some special but very important topics on linear stability are highlighted. Particularly, various aspects of the initial-value problem with respect to development of small-amplitude disturbances are considered in Chaps. 8–9. The problem of excitation of instability waves by external flow disturbances is considered in Chap. 10. When a linear instability disturbance grows beyond a certain amplitude threshold, it enters the region of its essentially nonlinear, but still deterministic development. The flow modulated by such nonlinear structures is frequently subjected to the phenomenon known as the secondary instability whose initial stage can be described by linear equations of motion. The secondary instability is discussed in Chap. 11.

The nonlinear development of disturbances is accompanied by wave interactions, base-flow distortions, and appearance of turbulent spots. The last part of the book (Chaps. 12–13) is devoted to the description of the main physical mechanisms and phenomena responsible for the final onset of turbulence.

In Appendix, some fundamentals of modern approaches for the prediction and control of the transition are discussed.

Supplementary Material

An interested reader can find details of different aspects of the transition of turbulence in near-wall shear flows in original publications, which are cited in *References* and *Further Reading* sections in the end of each chapter.

We decided to publish the manuscript as an e-book having in mind to make available a set of multimedia files of different value containing supplementary material including video clips and animations.

For those who like to feel the nature through numbers, the book is supplemented by a set of ‘toy’ MATLAB functions, which allow a reader to understand ‘how it works.’ The core routines cited in the book are accompanied by interface programs having the same generic names ending with ‘Test.’ To simplify the process and to give some guidelines, many chapters contain *Exercises*, which can be fulfilled with the help of the functions as a starting point.

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Physics of Transitional Shear Flows

Instability and Laminar-Turbulent Transition in

Incompressible Near-Wall Shear Layers

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