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BOOK REVIEW

ASYMPTOTIC THEORY OF SEPARATED FLOWS

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Cambridge University Press, 1998

The subject of this book, separated flows, is of great importance to researchers and engineers in their efforts to understand the complicated structure of many flows and also to develop appropriate engineering models for flows of practical interest. The authors concentrate on the former approach, namely, reviewing the theoretical advances in boundary-layer theory and separated flows.

The theory of boundary-layer flow and separation when the Reynolds number of the flow, Re, is asymptotically large has been of interest to researchers and engineers since Prandtl first developed his now classical theory for steady, two-dimensional laminar flows in 1904. Since then, many articles and books have been written on various aspects of the subject, especially for the case of two-dimensional steady flow. There was, and still is, great theoretical as well as practical interest in the characteristics of a moving fluid near a surface. Of special interest are the effects of flow displacement and flow separation which occur in many flows of engineering relevance.

It was known from a number of studies that flow separation was related physically to the action of an impressed adverse pressure gradient on the flow nearest to the surface. However, it was not until 1948 that Goldstein presented a mathematical theory valid near the point of separation that showed for the first time that the classical boundary-layer equations are singular at the separation point, at least for two-dimensional, steady flows. He was able to deduce that when the impressed pressure distribution was adverse in character, the velocity normal to the wall increased as $(x_s - x)^{-1/2}$ as the separation point, x_s, was approached.

Significant advances in our theoretical understanding of the singular nature of Prandtl's equations near the separation point did not come about until the late 1960s, notwithstanding the important contribution of Lighthill in 1953 on upstream influence in laminar boundary layers. A key study was that of Catherall and Mangler, in which they numerically integrated the boundary-layer equations past the point of zero skin friction in a nonsingular manner by allowing the pressure to be an unknown function which was determined as part of the solution. Shortly thereafter, K. Stewartson, A. Messiter, and V. Neiland, independently developed a new theory which allowed for the interaction of the local flow field and the induced pressure caused by a disturbance of some sort. This theory has generally become known as the "triple-deck theory" of viscous–inviscid interactions and is the subject of this excellent translation of an earlier Russian edition by four Russian experts who have made significant contributions to this field over a period of many years.

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Since the first studies on separated flows appeared, there has been a large effort directed towards the further understanding of separated flows as well as other related problems wherein viscous–inviscid interactions are essential to an understanding of the flow physics. This book, *Asymptotic Theory of Separated Flows*, provides a detailed theoretical treatment for one class of these problems, namely two-dimensional, laminar steady flows, although Chapter 5 does, in fact, consider some aspects of unsteady separation. While this is a somewhat narrow class of problems, the authors have presented a very detailed and complete theoretical discussion, along with references to the vast majority of other contributors to the subject matter under review.

The first four chapters present the core of the theory, beginning with a review of the classical theory and separation from a smooth surface in Chapter 1, continuing with flow separation from the corners of a body contour in Chapter 2. Chapter 3 considers the flow near the trailing edge of a thin airfoil, while separation at the leading edge of a thin airfoil is discussed in Chapter 4. In all these chapters, the theory is developed in sufficient detail so that a person with some knowledge of the method of matched asymptotic expansions can readily follow the steps in the analysis for the different problems under study. Also, others should be able to deduce the essential physical results of the relevant asymptotic theories, if so desired, without having to follow in detail the intricate steps needed to reproduce them.

Chapter 5 presents a discussion of unsteady boundary-layer separation, and is thus somewhat different from the chapters preceding it in that the physical mechanisms of separation differ from those of a steady two-dimensional flow. The approach is similar, however, using the method of matched asymptotic expansions to explore the flow characteristics near the singularities which appear in unsteady two-dimensional flows. Chapter 6 returns to steady flows with a discussion of the asymptotic theory of the separated flow past a blunt body, wherein the intent is to determine the limiting state for the steady flow behind a finite body as the flow Reynolds number tends to infinity. Finally, Chapter 7 discusses some of the numerical methods used by researchers to solve the resulting nonlinear partial differential equations that arise in interaction theory. Interestingly, it is only in this chapter that supersonic triple-deck theory is mentioned, primarily because the numerical approaches are simpler for this type of flow. It should be noted that other numerical methods which were developed by individual researchers to solve specific problems in interaction theory are not discussed or referenced in this chapter. These omissions are, perhaps, not surprising since the focus of this work is on the theoretical aspects of separated flows and not on the numerical methods employed by different individuals to solve specific boundary-value problems.

The authors present the theory in a clear, detailed manner, and the book is almost without typographical errors, insofar as I could tell. It is difficult to find much fault with this work. Perhaps the only criticism of this book is that it is almost entirely devoted to aerodynamics problems and to steady, two-dimensional, incompressible flows. There are many other problems to which the "triple-deck theory" has been applied with great success; for instance, three-dimensional steady flows, internal flows in pipes and channels, compressible flows in all speed ranges from subsonic to hypersonic, and further problems on unsteady flow effects for all of the areas noted above. Finally, the asymptotic methods discussed here have also found application in the study of boundary-layer stability and transition. However, the omission of these topics should in no way diminish the importance of this work. It only serves to reinforce the fact that the basic flow problems studied using asymptotic methods can serve as guides to provide researchers with valuable tools and insights to very complicated flow configurations.

This reviewer highly recommends this book, written by well-known contributors to the field, for both experienced and novice researchers in the field. It should serve as an important reference text for those interested in the asymptotic theory of separated flows.

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