# Preface

The purpose of this book is to expose students to the classical theories of aerodynamics to enable them to apply the results to a wide range of projects, from aircraft to wind turbines and propellers. Most of the tools are analytical, but computer codes are also available and are used by the students to carry out seven to eight projects during the course of a quarter. These computer tools can be found at http://mae.ucdavis.edu/chattot/EAE127/ along with the project statements.

The main focus is on aircraft and the theories and codes that help in estimating the forces and moments acting on profiles, wings, wing-tail and fuselage configurations, appropriate to the flow regime, i.e., subsonic, transonic, supersonic, viscous or inviscid, depending on the Mach number and Reynolds number.

The book culminates with a study of the longitudinal equilibrium of a glider and its static stability, a topic that is not usually found in an aerodynamics but in a stability and controls book. This chapter reflects the expertise of one of the authors (JJC), who has been involved for several years in the SAE Aero Design West competition, as faculty advisor for a student team, (http://students.sae.org/competitions/aerodesign/west/) and has developed the tools and capabilities enabling students to develop their own designs and perform well in the competition. As all airplane modelers know, placing the center of gravity in the correct location is critical to the viability of an aircraft, and a statically stable remote controlled model is a requirement for human piloting.

The material is presented in a progressive way, starting with plane, two-dimensional flow past cylinders of various cross sections and then by mid-quarter, moving to three-dimensional flows past finite wings and slender bodies. In a similar fashion, inviscid incompressible flow is followed by compressible flow and transonic flow, the latter requiring the numerical solution of the nonlinear transonic small disturbance equation (TSD). Viscous effects are discussed and also, due to nonlinear governing equations, numerical simulation is emphasized.

A set of problems with solutions is placed in Part III. It corresponds to final examinations given over the last 10 years or so that the students have 2 hours to complete.

Finally, the reader is assumed to have the basic knowledge in fluid mechanics that can be found in standard textbooks on this topic, in particular as concerns the physical properties of fluids (density, pressure, temperature, equation of state, viscosity, etc.) and the conservation theorems using control volumes. The reader is also assumed to master undergraduate mathematics (calculus of single variables, vector calculus, linear algebra, and differential equations). Three appendices are included in the book, summarizing the material relevant to the subject of interest.

Aerodynamics has a long history and it has reached a mature status during the last century. There are at least 20 books written on aerodynamics in the last 20 years (see references). Some of these are excellent textbooks and some are outdated or out of print. All of the existing texts are based, however, on small disturbance theories. These theories are essential to gain understanding of the physical phenomena involved and the corresponding structure of the flow fields. They also provide good approximations for some simple cases. For practical problems, however, there is a demand for accurate solutions using modern computer simulation. Small disturbance theories can still provide special solutions to test the computer codes. More important perhaps, they can provide a guideline to construct accurate and efficient algorithms for practical flow simulations. They are also used to develop the far field behavior required for the numerical solution of the boundary value problems. In general, the linearized boundary conditions and the restriction to Cartesian grids are no longer sufficient. Grid generation algorithms for complete airplanes, although still a major task in a simulation, are nowadays used routinely in industry. Hence, small disturbance approximations are no longer necessary and indeed full nonlinear potential flow codes, developed over the last two decades, are available everywhere. While it is argued that the corrections to potential flow solutions due to vorticity generated at the shocks can be ignored for cruising speed at design conditions, the viscous effects are definitely important to assess. Again, boundary layer approximations can be useful as a guideline to construct effective viscous/inviscid interaction procedures.

In the book we adopt this view in contrast to a complete CFD approach based on the solution of the Navier-Stokes equations everywhere in the field for more than one reason: it is more attractive, from an educational viewpoint, to use potential flow model and viscous correction. It is also more practical, since Euler and hence Navier-Stokes codes are more expensive and subject to errors due to artificial viscosity as a result of the discrete approximations. A simple example is the accurate capturing of the wake of a wing and the calculation of induced drag, still a challenge today; for the same reasons, the simulations of propellers and helicopter rotor flows are in continuing development, let alone, the problem of turbulence.

In the text, the formulation and the numerics are developed progressively to allow for both small disturbances and full nonlinear potential flows with viscous/inviscid interactions. Only a few existing books (two or three) address these issues and we hope to cover this material in a thorough and simple manner.

The book contains an extensive list of references on aerodynamics including textbooks, advanced and specialized books, classical and old books, flight mechanics books as well as references cited in the text.

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