Preface to the Second Edition

The first edition of this book appeared in the fall of 2010 both as a hard copy and e-book. Since then there has appeared, in the literature, numerous unsteady aerodynamics-related material, which deserves to be presented in a graduate textbook. Most of the new material is relevant to Chap. 8: Modern Topics. Here, a calculation method for propulsive force, lift generation and induced drag of a pitching-plunging thin finite wing is provided with a numerical example as an additional material. The unsteady 3-D boundary layer solution technique is introduced for prediction of the viscous drag to see if the propulsive force overcomes the drag. In addition, the ground effect on the air vehicles performing near ground is formulated to see how the lift and the propulsive forces are altered for the high and low aspect ratio wings.

The state-space representation of aerodynamics was introduced briefly in the first edition. In the present edition, more detailed discussion of the method is provided via numerical solutions for airfoils and finite wings of various aspect ratios even in the presence of ground.

Additional material, including bio-inspired and biological flows, related to the unsteady flows is also provided at the end of Chap. 9 to emphasize the present developments and future prospects.

Some more material is added to the Appendix so that no derivation of equations is left incomplete but not overdone in the text.

Needless to say, in the first edition there were a few typographical errors which have been detected and corrected for the second edition.

Dr. Christoph Baumann read the new material and took the necessary steps for the second edition, and K. M. Govardhana prepared the metadata of the book. Mehmet Tan provided the figure for the cover page. My wife Zeliha, once more, stood by me in all these times with great patience. Finally, I would like to express my gratitude and appreciation to all who made publication of this book possible.

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Ülgen Gülçat

Preface

Flying animate objects were present in the earth's atmosphere about hundreds of million years before the appearance of human-kind on earth. Only at the beginning of the twentieth century, was proper analysis of the lifting force made to provide the possibility of powered and manned flight. Prior to that, one of the pioneers of mechanics, Sir Isaac Newton had used 'his impact theory' in an attempt to formulate the lifting force created on a body immersed in a free stream. In the late seventeenth century, his theory was a failure due to calculation of insufficient lift generation which made him come to the conclusion that 'flying is a property of heavenly bodies'. In a similar manner, almost after two centuries, William Thomson (Lord Kelvin), whose contributions to thermo and gas dynamics are well known, proved that 'only objects lighter than air' can fly!

Perhaps it was the adverse influence of these two pioneers of mechanics on Western Europe, where contributions to the discipline of hydrodynamics is unquestionable, that delayed the true analysis of lift generation. The proper analysis of lifting force, on the other hand, was independently made at the onset of the twentieth century by the theoretical aerodynamicists Martin Kutta and Nicolai Joukowski of Central and Eastern Europe respectively. In about the same years, the Wright brothers, whose efforts on powered flight were ridiculed by the authorities of their time, were able to fly a short distance. Thereafter, in a time interval of a little more than a century, which is a considerably short span compared to the dawn of civilization, we see not only tens of thousands of aircraft flying in the earth's atmosphere at a given moment but we also witness unmanned or manned missions to the moon, missions to almost every planet in our solar system and to deeper space to let the existence of life on earth be known by the other possible intelligent life forms.

The foundation of the century-old discipline of aeronautics and astronautics undoubtedly lies in the progress made in aerodynamics. The improvement made on the aerodynamics of wings, based on satisfying the Kutta condition at the trailing edge to give a circulation necessary for lift generation, was so rapid that in less than a quarter century it led to the breaking of the sound barrier and to the discovery of

sustainable supersonic flight, which was unprecedented in nature and once thought to be not possible! In many engineering applications involving motion we encounter either forced or velocity-induced oscillatory motion at high speeds. If the changes in the excitations are rapid, the response of the system lags considerably. Similarly, the response of the aerodynamic systems cannot be determined using steady aerodynamics for rapidly changing excitations. The unsteady aerodynamics, on the other hand, has sufficient tools to give accurately the phase lag between the rapid motion change and the response of the aerodynamic system. As we observe the performances of perfect aerodynamic structures of nature, we understand the effect of unsteady phenomena to such an extent that lift can be generated with apparent mass even without a free stream. In some cases, when the classical unsteady aerodynamics does not suffice, we go beyond the conventional concepts, with observing nature again, to utilize the extra lift created by the suction force of strong vorticies shed from the sharp leading edge of low aspect ratio wings at high angles of attack. We implement this fact in designing highly maneuverable aircrafts at high angles of attack and low free stream velocities. If we go to angles of attack higher than this, we observe aerodynamically induced but undesirable unsteady phenomena called wing rock. In addition, quite recently the progress made in unsteady aerodynamics integrated with electronics enable us to design and operate Micro Air Vehicles (MAVs) based on flapping wing technology having radio controlled devices.

This book, which gives the progress made in unsteady aerodynamics in about less than a century, is written to be used as a graduate textbook in Aerospace Engineering. Another important aim of this work is to provide project engineers with the foundations as well as knowledge needed about the most recent developments involving unsteady aerodynamics. This need emerges from the fact that the design and analysis tools used by research engineers are treated as black boxes providing results with inadequate information about the theory and practice. In addition, the models of complex aerodynamic flows and their solution methodologies are provided with examples, and enhanced with problems and questions asked at the end of each chapter. Unlike this full text, the recent developments made in unsteady aerodynamics together with the fundamentals have not appeared as a textbook except in some chapters of books on aeroelasticity or helicopter dynamics!

The classical parts of this book are mainly based on ‘not so terribly advanced’ lecture notes of Alvin G. Pierce and basics of vortex aerodynamics knowledge provided by James C. Wu while I was a PhD student at Georgia Tech. What was then difficult to conceive and visualize because of the involvement of special functions, now, thanks to the software allowing symbolic operations and versatile numerical techniques, is quite simple to solve and analyze even on our PCs. Although the problems become more challenging and demanding by time, the development of novel technologies and methods render them possible to solve provided that the fundamentals are well taught and understood by well-informed users. The modern subjects covered in the book are based on lecture notes on ‘Unsteady Aerodynamics’ courses offered by me since the past several years at Istanbul Technical University.

The first five chapters of the book are on the classical topics, whereas the rest covers the modern topics, and the outlook and the possible future developments finalize the book. The examples provided in each chapter are helpful in terms of application of relevant material, and the problems at the end of each chapter are useful for the reader towards understanding of the subject matter and its future usage. The main idea to be delivered in each chapter is given as a verbal summary at chapters' end together with the most up-to-date references. There are ten Appendixes that supplement the formulae driven without distracting the uniformity of the text.

I had the opportunity to reuse and borrow some material from the publications of Joseph Katz, AIAA, NATO-AGARD/RTO and Annual Review of Fluid Mechanics with their kind copyright permissions. Dr. Christoph Baumann read the text and made the necessary arrangements for its publication by Springer. Zeliha Gülçat and Canan Danışman provided me with their kind help in editing the entire text. N. Thiyagarajan prepared the metadata of the book. Aydın Mısırlıoğlu and Fırat Edis helped me in transferring the graphs into word documents. I did the typing of the book, and obtained most of the graphs and plots despite the 'carpal tunnel syndrome' caused by the intensive usage of the mouse. Furthermore, heavy concentration on subject matter and continuous work hours spent on the text showed itself as developing 'shingles'! My wife Zeliha stood by me in all these difficult times with great patience. I would like to extend my gratitude, once more, to all who contributed to the realization of this book.

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