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Book Reviews

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Aerodynamics of Low Reynolds Number Flyers

Wei Shyy, Yongsheng Lian, Jian Tang, Dragos Viieru, and Hao Liu, Cambridge University Press, New York, 2007, 177 pp., $80.00

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During the past 10 years a new frontier of aeronautical engineering has been opened up triggered by the recognition that very small air vehicles (micro air vehicles or MAVs) may have great potential for surveillance and monitoring missions. Such vehicles are usually defined as having dimensions not exceeding 15 cm in any one direction and maximum flight speeds of around 10 m/s. As a consequence, these vehicles operate at Reynolds numbers of less than 10^5.

The authors of this book, active pioneers of this new field, have assembled the first comprehensive treatment of the major new aerodynamic aspects pertaining to MAVs. They start by giving examples of the flight characteristics of birds, bats, and insects in various flight modes and point out that some birds can fly at 140 body lengths per second compared to the 32 body lengths per second of the Mach 3 SR-71 "Blackbird" and achieve roll rates far in excess of typical aerobatic aircraft. This leads them to the discussion of the scaling laws governing the effect of the various parameters, such as wing area, wing span, weight, wing loading, flapping frequency, etc., on the flight characteristics and the power required in flapping flight.

The additional three chapters are devoted, first, to the low Reynolds number aerodynamics of fixed wings, followed by chapters on flexible wings and flapping wings. In the fixed-wing chapter they give a nice introduction to the phenomena occurring at low Reynolds number (laminar separation, separation bubble formation, transition to turbulence) and discuss the modern methods to predict these phenomena using transition modeling, the e^N method for transition onset prediction, and Reynolds-averaged Navier–Stokes computations. They include example calculations for the SD7003 airfoil as well as a discussion of the effect of freestream turbulence and unsteady freestream conditions. Also, the dynamic stall phenomenon is explained and the effect of wing aspect ratio and of the tip vortices is covered.

The chapter on flexible-wing aerodynamics starts out with a discussion of the birds' and bats' ability to rapidly adjust wing camber and geometry to accommodate rapidly changing flight conditions. Membrane-wing MAVs have recently been developed with the intent of imitating the characteristics evolved by the biological flyers over millions of years. To this end, the authors give the reader some insight into the modeling needed to understand and predict the flight behavior of membrane-wing MAVs, using linear or hyperelastic membrane modeling and coupled fluid-structural dynamics computations using modern computational fluid and structural dynamics codes.

In the final chapter on flapping-wing aerodynamics the authors introduce the reader to the vortex shedding phenomena that are generated by flapping wings in hovering and forward flight. They show the importance of flapping frequency and amplitude on lift and thrust generation, and the need to describe the flow by means of fully unsteady flow analysis methods with the help of an additional similarity parameter, that is, the Strouhal number or reduced frequency. They conclude this chapter with an instructive illustration of the vortex shedding from the hovering hawk moth and from an elliptic airfoil flapping in the hovering mode.

Only 15 years ago, as this reviewer knows from personal experience, the study of flapping-wing aerodynamics was regarded as a rather "academic" activity of little practical interest for aeronautical engineers. It is gratifying to see the many papers which have been published on MAV aerodynamics in the past decade. This 177-page book gives a good introduction to this subject. It is well written and illustrated with 29 color and 130 black and white figures. It also has a quite comprehensive reference list. Therefore, it should be of value to scientists and engineers who wish to familiarize themselves with the aerodynamics of birds, insects, and micro air vehicles. In addition, students and anyone else who wishes to learn about the intricacies of aerodynamic lift and thrust generation will benefit from reading parts of this book.

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