

Preface

Wind Energy has flourished over the last 20 years. At the time of this writing, approximately 40 GW of wind power production capacity, equivalent to 80 billion US \$ in investment, is added to the worldwide energy portfolio annually.

About 2,40,000 (IEA Wind 2012 annual report) engineers are working in this field, and many of them are confronted with challenges related to aerodynamics. Even special academic programs (one of them being the M.Sc. Program in Wind Engineering at the consortium of universities in Schleswig-Holstein, the northernmost province of Germany) now are educating young people in this field. From personal experience, the author knows how difficult it is to navigate through the jungle of scientific literature without being injured before having learned all the basics. This textbook intends to help young and old interested people to gain easier access to the basics of the fluid mechanics of wind turbines.

The scope of this book is to take the reader on an interesting journey from the basics of fluid mechanics to the design of wind turbine blades. The reader's basic knowledge of mathematics (Vector calculus) seems to be necessary for understanding, whereas fluid mechanics will be explained in what amounts to a crash course. But there should be no mistake: fluid mechanics being *non-linear*, even as an applied science, is a complicated affair and can only be learned and understood by one's *own* problem solving. This is especially true when investigating *turbulent* flow which is of utmost importance when investigating mechanical loads on wind turbine parts. Therefore, the estimated amount of effort necessary for solving our selected problems at the end of each chapter ranges from 10 min to 10 months.

The author will try to give the beginning reader a glimpse of established knowledge about the aerodynamics of wind turbines. For the more familiar reader, this book will facilitate the discovery of (and hopefully understanding of) relevant advanced papers. In any event, all readers will glean a deeper understanding which will allow them to perform analyses either by hand or by using computer codes.

The structure is as follows: an introduction is given to inform the reader about the specific relevance of wind turbine aerodynamics, while touching on some interesting historical examples. Then a chapter on installed windmills and wind turbines is added to describe the basics of mainstream and unconventional technology. After that we are ready to tackle our general framework: the laws of fluid mechanics. I will try to limit the contents to those topics that are closely related to wind, understood as turbulent flow in the lower (boundary layer) part of the

atmosphere. Because the rotor swept area now easily reaches several *hectares* ($= 10^4 \text{ m}^2$) something must be said about real-world inflow conditions, which are not constant from a spatial or temporal point of view. Chapter 5 is the core of the book and explains the various versions of *Momentum Theory* as well as its limitations, followed by a description of applications of its counterpart: *Vortex Theory*. After exhausting these classical methods, we then have to present the modern approach of solving the differential equations called *Computational Fluid Dynamics* in some detail. Many efforts have been expended over the last 15 years to bridge the gap from older, sometimes called simpler, theories to actual measurements using these computational methods. This leads directly to a transition in the next chapter to a discussion of free-field and wind tunnel measurements. After that we will try to get even closer to practical, real things. This means that we try to give examples of actual blade shapes from industry. We conclude with summarizing remarks and an overview of possible future developments.

As this text grew out of my lectures on wind turbine aerodynamics in the first year of our international Master of Science Program, it is targeted toward this student audience. Nevertheless, I have tried as much as possible to make it valuable and informative for a much broader group of readers.

Kiel, Germany, April 2014

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<http://www.springer.com/978-3-642-36408-2>

Introduction to Wind Turbine Aerodynamics

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2014, XXII, 265 p. 233 illus., 136 illus. in color.,

Hardcover

ISBN: 978-3-642-36408-2