Passive and active flow augmentation
From diffusers to multi-rotor machines

De Oliveira Andrade, Gael; Balbino Dos Santos Pereira, Ricardo; van Bussel, Gerard; Avallone, Francesco; Ragni, Daniele

Publication date
2017

Document Version
Final published version

Citation (APA)
De Oliveira Andrade, G., Balbino Dos Santos Pereira, R., van Bussel, G., Avallone, F., & Ragni, D. (2017). *Passive and active flow augmentation: From diffusers to multi-rotor machines*. 184-184. Abstract from Wind Energy Science Conference 2017, Lyngby, Denmark.

WESC2017 - DTU
COPENHAGEN 2017

BOOK OF ABSTRACTS

WESC2017 – Wind Energy Science Conference
Technical University of Denmark, Lyngby
June 26th – 29th, 2017

Preface

Wind Energy Science Conference 2017 (WESC-2017) is held at the Technical University of Denmark in Lyngby during June 26-29, 2017. This conference is the first of a series of bi-annual conferences launched by the European Academy of Wind Energy (EAWE). The purpose of the conference is to gather leading scientists and researchers in the field of wind energy to present their latest findings. The conference aims at covering all scientific topics in wind energy, comprising from most fundamental aspects to recent applications. It provides a world-wide forum for scientists to meet each other and exchange information of all aspects of wind energy, including aerodynamics, turbulence, wind resource assessment, wind farms and wakes, aero-serve-elasticity, loads, structural mechanics, control, operation and maintenance, generator technology, grid integration, structural design and materials, new concepts, as well as community acceptance, environmental aspects, and economics.

This volume of abstracts comprises all presentations of the conference, including two plenary lectures, and nearly 370 contributed papers, presented in either oral sessions or during 13 mini symposia. The abstracts are sorted chronologically after the day of presentation, corresponding to the way they appear in the conference programme. At the end of the book you will find a list of presenting authors, listed alphabetically, and the page number where their abstract appear.

I like to thank the scientific committee and the local organizing committee for their work with the evaluation and selection process. In particular, I thank Marianne Hjorthede Arbirk for her invaluable help in preparing the conference and this book of abstracts.

Jens N. Sørensen, chairman WESC-2017
Lyngby, June 2017

Passive and active flow augmentation: from diffusers to multi-rotor machines

G.L. de Oliveira[a], R.B. Pereira[a], G.J.W. van Bussel[a], F. Avallone[a] and D. Ragni[a]

Flow augmentation consists in modifying mass flow across the actuation plane of a rotor to enhance energy extraction or propulsive efficiency. The talk sketches the distinction between passive and active rotor augmentation strategies. Power coefficient trends are compared analytically while numerical results illustrate differences in flow topology. Rotors are stylized as actuator disks that exert homogeneous normal forces on the steady flow of inviscid fluids to highlight the distinctive features of each augmentation principle.

Passive augmentation principles have been well documented because they guide the design of ducted, shrouded and diffuser-augmented wind turbines[1-6]. These axisymmetric bodies decrease average static pressures on the rotor plane to increase mass flux and power coefficient. Rotor-body interactions are dominated by conservative forces[5,7]: the bodies don't exchange energy with the fluid but act as augmenting devices and affect global energy balance by changing rotor state. Virtual work arguments show that bodies exert streamwise forces[4,6] that can be related with the power coefficient through the law of de Vries[1,6].

Active flow augmentation is a rather recent theoretical concept[8]. Its simplest energy extraction embodiment consists of an upstream actuator that accelerates flow onto a downstream actuator. This augmentation strategy is coined as active because the upstream actuator injects (spends) energy into the flow for the downstream actuator to extract (produce) energy from a greater mass flux than if it were alone. The interaction mechanism depends on the action of non-conservative forces and actuators interact exclusively through changes in total flow enthalpy when they are sufficiently far apart. No pressure interactions occur in this asymptotic case and a closed solution exists together with an analytical power coefficient law. Parallels can be drawn with wake ingestion propeller setups[9] but no practical energy extraction realizations have been attempted yet.

Passive and active flow augmentation concepts are different but we hope that parallels between them shed further light on the physics of energy extraction from ideal fluid flows. The communication concludes with a few reflections meant to trigger an open discussion about the implications and applicability of the discussed theories.

---

[a] Wind Energy Research Group (AWEP/WE), Aerospace Engineering Faculty (LR), TU Delft, Delft 2629HS, The Netherlands.

[1] de Vries, O. AGARDograph **243** (1979) .
[2] Van Bussel, GJ. *J. of Physics: Conf. Series* **75**(1) 012010 (2007).
[3] Jamieson, P. *Wind Energy* **11** 445 (2008)
[4] Werle, and Presz. WM. *J. of Prop. and Power* **24**(5) 1146 (2008)
[5] Sorensen, J.N. General Momentum Theory for Horizonthal Axis Wind Turbines. (Springer, 2016)
[6] de Oliveira et al. *J. of Physics: Conf.Series* **753**(2) 022005 (2016)
[7] van Kuik et al. J. Fluid Mech. **750** 284 (2014)
[8] de Oliveira G et al. Is there any benefit in placing a propeller ahead of a wind turbine? *Proc. Royal Society A* (To be submitted April 2017)
[9] de Oliveira G et al. Analysis of wake ingestion setups with the infinitesimal streamtube formulation, In *Aerospace Science and Engineering* (To be submitted May 2017)

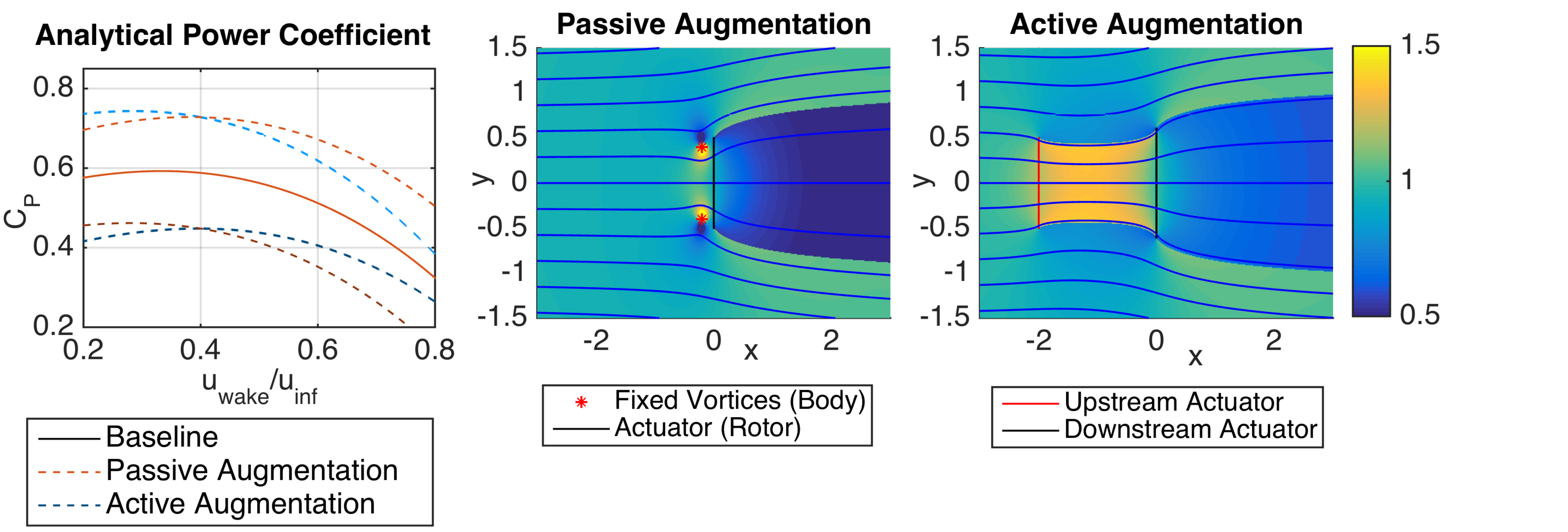

Figure 1: (a) Illustrative Analytical Power Coefficient Curves. (b) Passive Augmentation Flow Topology. (c) Active Aurgmentation Flow Topology. Figure (b) and (c) were obtained with a steady state Lagrangian numerical solver of the planar vorticity equation: color representa velocity magnitude (see colorbar) and blue lines represent select streamlines.