The effect of the number of blades on wind turbine wake

A comparison between 2- and 3- bladed Rotors

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INTRODUCTION

In order to improve the performance of a wind farm, several aerodynamic concepts have been investigated and discussed [1]. Even though, these concepts have led to improved wind turbine arrangements in a farm park, there is still potential for further improvement in wind parks performance. Herein the rotor design of the turbines is offering various interesting possibilities.

In the present work, the effect of the number of blades on wind turbine wake is investigated. Therefore a three bladed rotor is compared with two different concepts for 2-bladed rotors. Herein the performance characteristics as well as the wake are analyzed.

In the wind power industry the development and research focused mostly on 3-bladed turbines. This is due to the disadvantages of two bladed turbines compared to 3-bladed rotors, such as the higher noise emissions, the distracting visual effects and the unfavorable dynamic behavior. As the offshore wind energy marked is gaining importance, the 2-bladed turbines are getting more significant again, this is due to the fact, that the drawbacks are not as relevant offshore and the big advantage of one rotor less is strongly decreasing the costs of the wind turbine[2].

OBJECTIVE

The objective of the work is, to show how rotors, showing the same performance characteristics, with different number of blades are influencing the wake and thus, whether a lower number of blades has a positive effect on the inflow conditions and consequently the power output of a turbine operating in the wake of the turbine with the rotor with a varying number of blades.

METHODS

Rotordesign

The rotor design is based on the rotor developed at the Department of Energy and Process Engineering at NTNU Trondheim which is described in [3] and is also the 3-bladed rotor used in the study.

For the design of the 2-bladed turbines it was important that the rotors are comparable to the existing 3-bladed rotor. Therefore the 2-bladed rotors where designed to have the same maximum CP value as the existing 3-bladed turbine.

To achieve this goal many different rotors where designed, adjusting the chord length and the twist angle. The performance characteristics of the different designs were tested with the software QBlade. The rotors showed the best agreement in the simulation were manufactured and tested.

- **Rotor 1**: 3-bladed rotor developed at NTNU
  Optimum at TSR 6
- **Rotor 2**: 2-bladed rotor same aspect ratio
  1.0 x Chord length, 0.7 x twist angle
  optimum at TSR 7
- **Rotor 3**: 2-bladed rotor same solidity
  1.5 x Chord length, 0.95 x twist angle
  Optimum at TSR 6

The three rotors are shown in Figure 1. They were manufactured using a 3D printer based on the PolyJet technology. To see if the 3D printing technology works for manufacturing the blades the performance characteristics of the 3-bladed printed rotor were compared to the 3-bladed milled aluminium rotor already existing at NTNU.

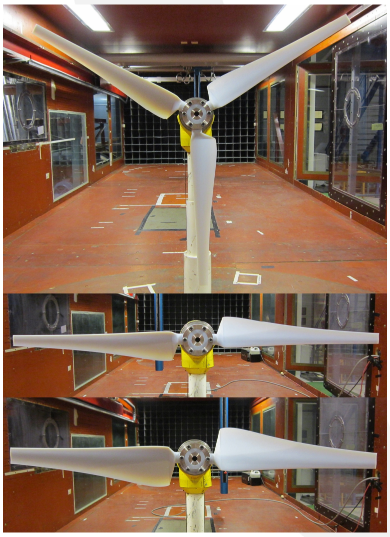

Figure 1: Three tested rotors mounted on the model turbine in the NTNU wind tunnel

Experimental Setup

The experiments were conducted in the closed-return wind tunnel of the Department of Energy and Process Engineering at NTNU. The rotors were mounted on the model turbine described in [3]. A sketch of the experimental setup is depicted in Figure 2.

- Inlet velocity $U_\infty = 10.0$ m/s
- Low turbulence $u'/U_\infty = 0.23\%$

Velocity measurement

- DANTEC 2-component LDV system

Performance measurements

- Thrust force with 6-component force balance
- Torque force with torque transducer in turbine

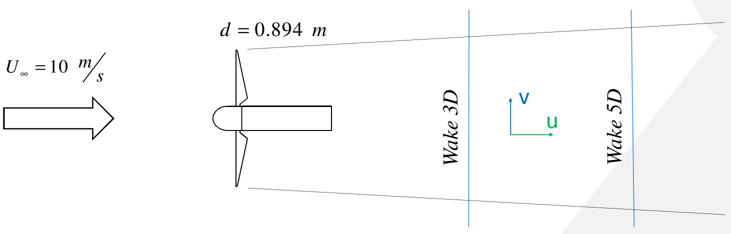

Figure 2: Sketch of experimental setup

RESULTS

Performance Characteristics

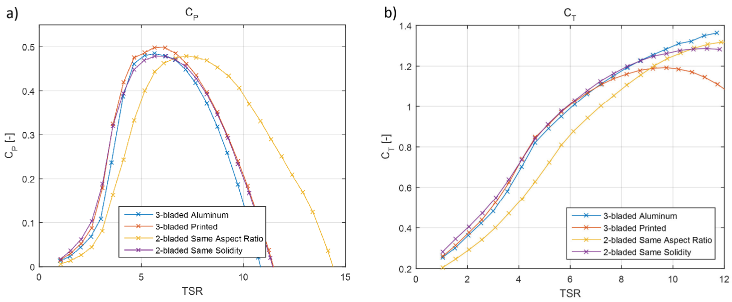

Figure 3: Performance characteristics from experiment a) power coefficient b) thrust coefficient

The maximum Power coefficients are all in the same region and the ones for the 2-bladed turbines are only 2% smaller.

The thrust coefficient shows the same behaviour at low TSR for the different rotors, only the 2-bladed rotor with the same solidity shows smaller values for the thrust coefficient in the low TSR region.

Velocity Deficit

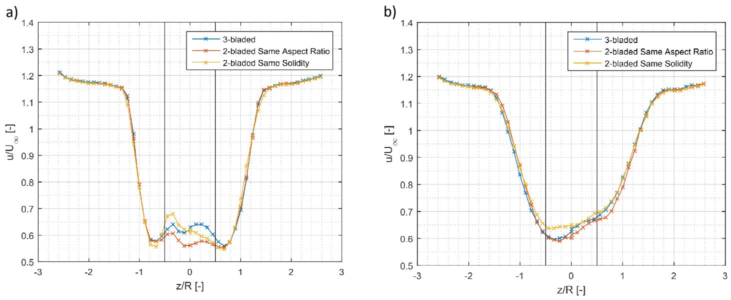

Figure 4: Normalized velocity at hub height from experiment with turbine rotor borders, a) 3D downstream of turbine, b) 5D downstream of turbine

2D Turbulence Intensity

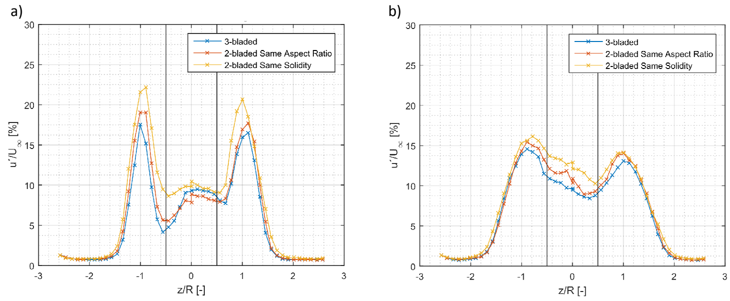

Figure 5: 2D turbulence intensity at hub height from experiment with turbine rotor borders, a) 3D downstream of turbine, b) 5D downstream of turbine

CONCLUSIONS

The performance characteristics from the experiment match the results obtained in QBlade.

The printed 3-bladed rotor has almost the same performance characteristics as the milled aluminium rotor.

The velocity deficit in the wake is very similar for all tested turbines, especially at the outer region of the wake. The major differences can be observed in the region directly behind the turbine. Consequently this regions have to be observed closer.

The turbulence intensity shows a clearer trend, whereas the 3-bladed rotor causes the smallest fluctuations followed by the rotor with the same aspect ratio and the rotor with the same solidity which generates the biggest fluctuations in the wake. Nevertheless the differences are rather small and have to be investigated closer.

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