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Load reduction of wind turbines using trailing edge flaps

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Abstract

Horizontal axis wind turbines have become an attractive renewable energy source due to their low carbon foot print. It was the aim of this study to reduce fatigue inducing variations of the blade root bending moment and thus enable the construction of lighter structures which further reduces the carbon footprint. Within the Smart Blades project the IWT-7.5-164 wind turbine has been used to investigate the feasibility of using trailing edge flaps as active control mechanism for load reduction. The analysis has been conducted using the German Aerospace Center's in-house comprehensive rotor simulation code S4 to simulate the aerodynamics as well as the structural deformation. For a tilted rotor without flaps the blade root bending moment acting perpendicular to the rotor plane has been observed to undergo a characteristic cyclic variation due to the tilt and gravity. Adding trailing edge flaps with a constant deflection alters the mean bending moment of the cyclic variation. A following study addressed the effect of using a sinusoidal flapping motion for a range of flapping amplitudes and phases. As a result a configuration has been identified that eliminates the cyclic variation of the blade root bending moment.

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Keywords: Bending moment; fatigue; flaps; IWT-7.5-164; smart blades;wind turbine

1. Introduction

Wind turbines have become an increasingly popular renewable energy source due to their low carbon footprint. Over their lifetime their carbon footprint incurred during manufacturing and construction averages out to 4.64 g of CO_2 equivalent per kWh produced [1]. This value may further be reduced by reducing the broad range of loads

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acting on a wind turbine and thus reducing the fatigue of critical components. Consequently lighter structures may be constructed which results in an even lower CO_2 emission during their construction.

The federally funded project Smart Blades has been initiated to address this issue by investigating various active and passive control mechanisms that reduce the loads acting on the blade of a wind turbine. In passive mechanisms the blade has been designed to respond to a bending deformation by twisting along its axis and vice versa. This feature which is known as bend-twist coupling is used to design a blade that changes its shape according to the aerodynamic loads acting on it. Active control mechanisms in contrast use mechanical components to lower the loads acting on the blade. In this study the active control mechanism of employing a trailing edge flap (TEF) is presented. The influence of a TEF has been investigated with respect to the blade root bending moment acting perpendicular to the rotor plane in order to reduce fatigue loads acting on the turbine. Fig. 1 shows the schematics of the TEF. In this study the flap defined ranges from 80.5 %R to 92.7 %R while having a depth of 20% chord. Maximum flap deflection angles η_F of ±10° were considered.

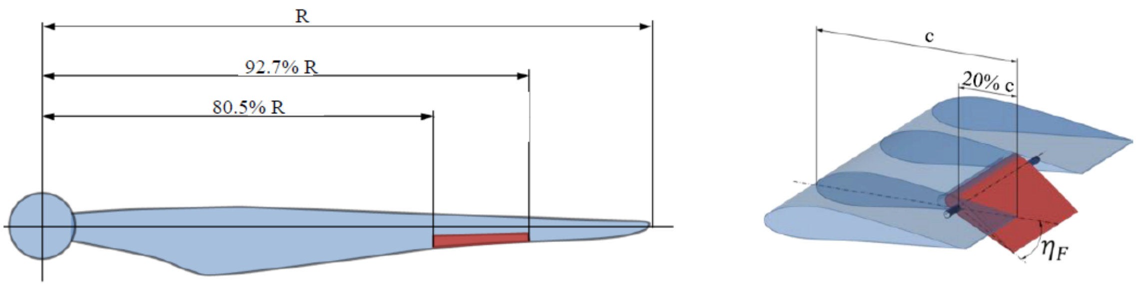

Fig. 1. Parameters of the TEF.

For the analysis the 3 bladed IWT-7.5-164 turbine has been used which has a radius of 82 m and produces a rated power of 7.5 MW [2]. The turbine has been designed by Fraunhofer IWES and Leibnitz Universität Hannover for this project. It has a pre-cone of 2° and a rotor tilt of 5°. Full information on the turbine geometry is given in [2]. All of the investigations presented in this study have been performed at the turbine's nominal wind speed of 11 m/s and rated rotational speed of 1.05 rad/s.

Nomenclature

a_0, a_k, b_k	Fourier coefficients [Nm]
c	chord length [m]
c_L	lift coefficient [-]
R	blade radius [m]
TEF	trailing edge flap
α	angle of attack [°]
η_F	current trailing edge flap deflection angle [°], positive towards pressure surface
$\hat{\eta}_F$	deflection amplitude of trailing edge flap [°]
φ	phase shift [°]
ψ	azimuthal position of rotor [°], 0° when blade 1 points downwards

2. Computational setup

For the simulation of the wind turbine with TEF, DLR's in-house comprehensive rotor simulation code S4 [3] has been used. The code calculates the aeroelastic interaction of the aerodynamics acting on the blades and their structural deformation. Following is a brief description of both modelling aspects. In this analysis a positive flap deflection is defined as a flap motion towards the pressure surface of the blade as seen in Fig. 1.