Testing of a new morphing trailing edge flap system on a novel outdoor rotating test rig

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1. Introduction

Considerable research on SMART blade technology has been conducted for more than 10 years and has shown big potentials for load reduction on MW turbines using distributed control for alleviation of the fluctuating loads along the blade span [1]. However, the requirements by the wind turbine industry of robust actuator solutions where the strongest specifications mean no metal and electrical parts in the blades have so far limited the use of the smart blade technology on wind turbines.

The development of the morphing trailing edge flap system to be presented in the present paper, also called the Controllable Rubber Trailing Edge Flap (CRTEF), was initiated in 2007. The first prototype was tested in the laboratory in 2008 and in late 2009 the CRTEF system was tested on a 2mx1m blade section in the Velux wind tunnel in Denamark [2]. From 2011 to 2014 the INDUFLAP project was conducted with the overall aim to transfer the technology from laboratory conditions to industrial manufacturing and application [2]. An important part of this work was the testing of the flap system on an outdoor rotating test rig in order to reduce the gap in test conditions between wind tunnel testing and full scale testing on a MW turbine. The main objective with the development and application of the rotating test rig was: 1) to test the flap system under rotating conditions with a g-loading that is comparable with the conditions on a full scale turbine; 2) to measure the performance of the flap system in real atmospheric turbulent inflow and 3) to test the flap technology in a size not that far from a full scale application.

2. Approach

The flap system comprises a morphing trailing edge flap (15% of the total chord) manufactured in an elastic material and with voids inside in two layers close to the pressure side and to the suction side, respectively. The voids can be pressurized with a fluid medium which can be air or an incompressible fluid. When one of the two layers is pressurized the flap deflects as shown in Figure 1. The flap system is without any mechanical and metal parts.

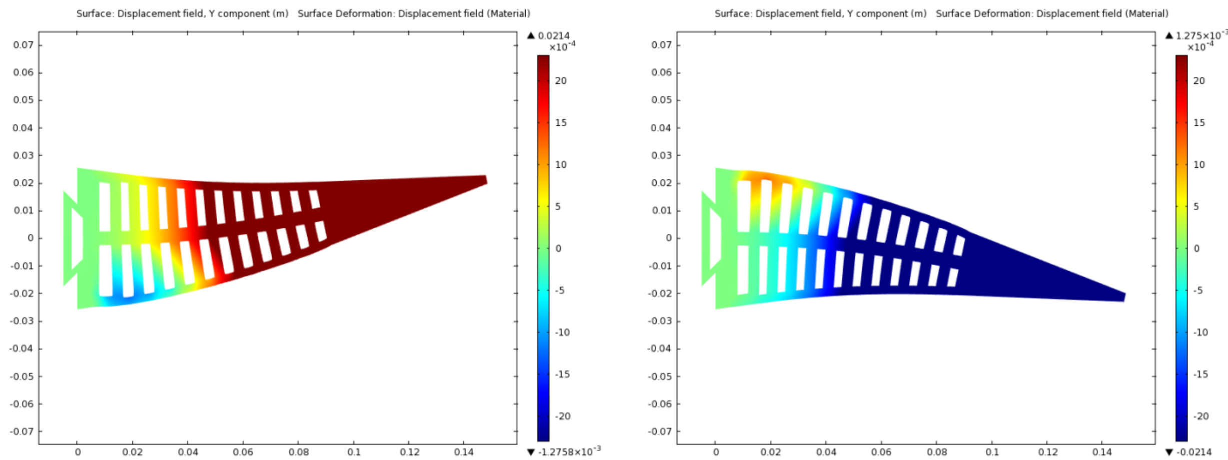

Figure 1 To the left, the lower row of voids is pressurized giving an upward deflection and to the right the upper row of voids is pressurized giving a downward deflection.

The industrial production of the present prototype has been performed at the company REHAU (project participant in the above mentioned INDUFLAP project) in kind of a multi component system comprising an enforcement structure and two elastic active elements regulated in deformation by a pressurized fluid medium. Fabrication of the active elements was performed by a continuous thermoplastic extrusion process in form of a quasi endless 12 chamber hollow profile. For manufacturing the sealed ends of the hollow profiles, a special method of a contact welding process was developed.

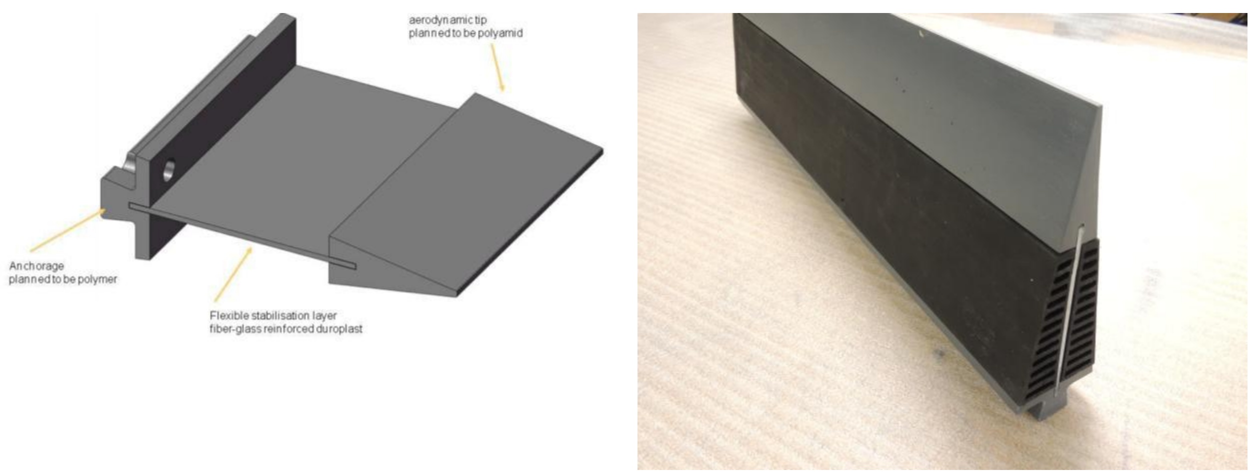

Figure 2 To the left is shown the load carrying components of the flap. To the right the parts are assembled but not glued together.

The rotating test rig was built on a 100kW turbine platform situated at the test site at DTU Risø Campus. A 10m long boom was designed to carry a 2m x 1m blade section with the 15% trailing edge flap system as shown in Figure 3. A counter weight was mounted on a shorter boom opposite to the blade section. Control options comprise both a full motor/generator 100 kW variable speed drive and a pitch system to rotate the boom with the blade section.

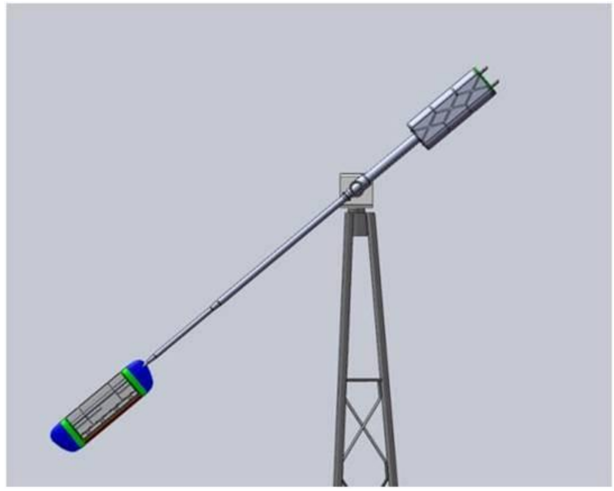

Figure 3 To the left is shown the 2x1m blade section + end caps before mounting the 2m long flap. To the right a sketch of the rotating test rig.

Instrumentation of the blade section comprised 2x64 pressure taps for measurement of the chordwise pressure distribution on the mid part of the blade section as well as for monitoring the variation of the loading influenced by the low aspect ratio of the blade section. To correlate the pressure measurements with the unsteady inflow, two five hole pitot tubes were mounted on the blade section.

The boom was installed on the turbine platform in June 2014, followed by a 1½ month measurement campaign in September and October 2014.

Figure 4 The photo to the left shows installation of the boom with the blade section in June 2014. On the photo to the right the blade section with the flap (black colour) can be seen as well as the two five hole pitot tubes.

3. Results

During the relative short measurement period that was available for the first measurement campaign on the rotating test rig in the autumn 2014 the focus was on characterization of the flap performance using prescribed flap variations. An example is showed in Figure 5 where the flap angle was changed with 10 deg. each 10 seconds. The aerodynamic normal force integrated from the measured pressure distribution is seen to change with the flap angle. The unsteadiness in the inflow due to the turbulence and tower shadow is also clearly seen in the aerodynamic loading.

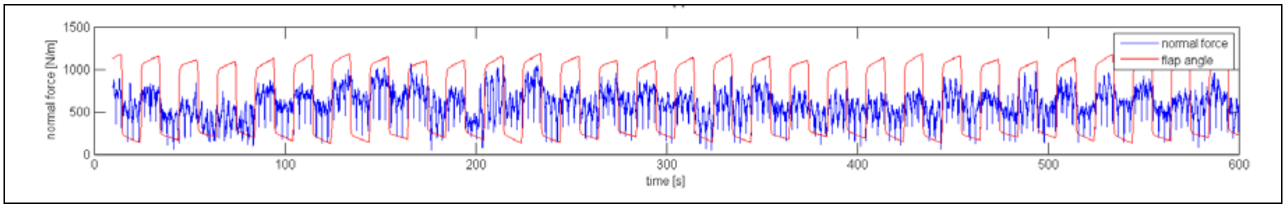

Figure 5 The normal aerodynamic load force on the blade section (blue curve) for a flap angle variation of total 10 deg. (red curve) each 10 sec.

For a rotational speed of 20 rpm. a number of measurements were performed for the flap angle in a +5 deg. and -5 deg. position and for different wind speeds and pitch settings. Based on these measurements the results shown in Figure 6 were derived. The figure to the left shows the normal force as function of the measured inflow angle for the two flap positions. To the right the flap performance is shown relative to the influence of change in loading from a change in pitch. From that figure it can be seen that about 2½ to 3 deg. of pitch gives the same change in loading as the 10 deg. {+5 deg. (green symbols), -5 deg (red symbols)} change of flap angle.

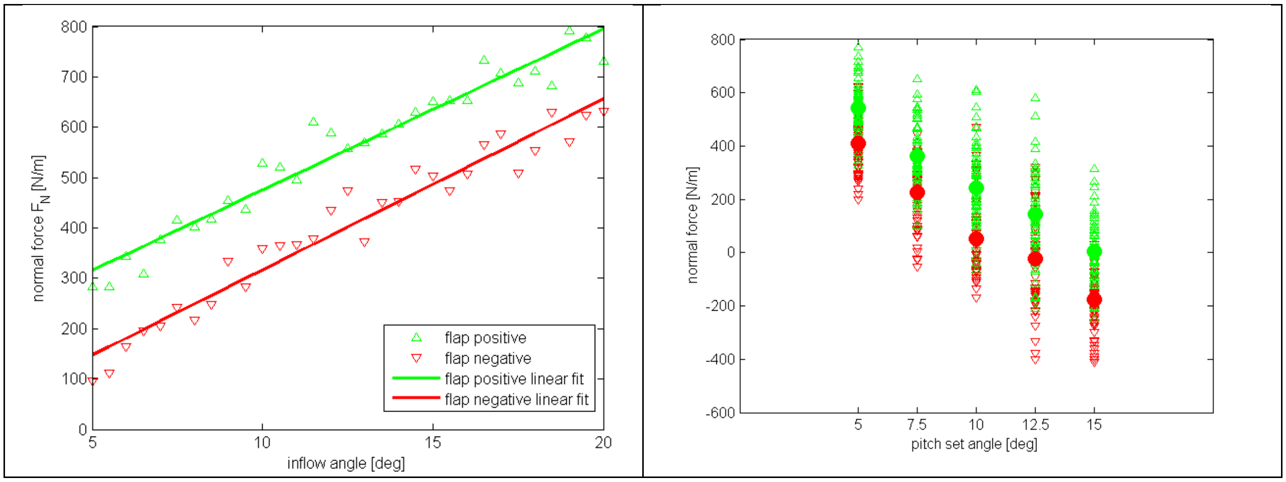

Figure 6 The graph to the left shows the normal force on the blade section as function of measured inflow angle for plus/minus 5 deg. flap angle. To the right is shown the normal force on the blade section for plus/minus 5 deg. flap angle as function of the pitch setting of the flap angle.

4. Conclusion

The morphing trailing edge flap concept also called the Controllable Rubber Trailing Edge Flap has been developed over the last 10 years. Recently it was tested on a novel outdoor rotating test rig intended to reduce the gap between wind tunnel testing of the flap technology and full scale tests on a MW turbine. The tests demonstrated that the flap system can work under the g- loading and the overall performance of the flap system can be characterized in the way the load change from 1 deg. change of the pitch of the blade section corresponds to about 3-4 deg. change of the flap angle.

5. Learning objectives

- It is demonstrated that the newly developed rotating test rig for testing SMART blade technology is an important facility that will reduce the risk and costs for the final introduction and application of the flap technology on full scale turbines
- Insight into flap aerodynamic performance in real turbulent inflow
- The measured performance of the present flap shows that the same load change from 1 deg. pitch of the section corresponds to 3-4 deg. change in flap angle

Acknowledgements

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6. References

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