Abstract No.

Smart blades with actively controlled compliant skin

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As new materials are developed to make wind turbine blades lighter and recycle friendly, new opportunities emerge to design smart materials that tackle fundamental fluid dynamic problems, such as flow separation. To this aim, we introduce a technology tailored to prevent flow separation through an actively compliant skin on the suction side of a blade cross-section. The skin oscillates to enhance mixing in the boundary layer and prevent flow separation.

The concept is demonstrated with a NACA 0025 3D printed blade section whose suction side is covered with an off the shelf polymer magnetoelastic membrane. This type of membrane provides the required structural stiffness for the prototype, as opposed to low stiffness attempted membrane combinations of silicon rubber with dispersed iron particles. The off the shelf approach proved also to be economically affordable and time efficient to manufacture the blade.

Figure 1a shows the blade subject to membrane slow actuation and figure 1b the membrane subject to fast actuation. The membrane is actuated via two electromagnets positioned inside of the blade. Hence, the assembly avoids moving joints and ensure that the electronics remain isolated from the environment. The empty space inside of the blade is filled with foam to support external pressure and help the membrane keep its shape. The membrane extends about three quarters of the span of the blade and is glued to the assembly by means of a thin layer of silicon rubber.

The control of the membrane is implemented with an Arduino Uno microcontroller and the power electronics with an L298N motor driver. Two pulse width modulation (PWM) duty cycles are used to control the voltage fed into the electromagnets and hence the displacement of the membrane. A time delay between the two duty cycles controls the speed of the actuation. The deformation of the membrane was measured at three actuation speeds in air and water with an optosensor positioned inside the body of the blade. The performance of the membrane was satisfactory and similar in both environments.

Load cell measurements are carried with 6-axis load cell and sampled at 1000 Hz in a water flume. The blade is positioned at a fixed angle of attack and the membrane actuated at three different speeds. The flume is 9 m long, 0.4 m wide and 0.9 m high with a flat, horizontal bed. The mean water depth is set to 0.5 m. Results show that the lift force increases by about 1% with increasing membrane actuation frequency, whilst drag reduces by about 7%. Power spectrum density of the force signals shows frequency peaks at the corresponding actuation frequency of the membrane. Future and ongoing work includes evaluating the impact of such technology in the torque and thrust outputs of a turbine rotor.

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Images:
Link: https://s3-eu-west-1.amazonaws.com/static.vcongress.de/cms/forwind/paper/a240f8cd-5d05-4ce6-a19e-9fe13e22b42b.png
Description: Figure 1. Cross-section of blade a) with slow actuation and with flow separation and b) with fast actuation and flow reattachment

References: