Morphing Blades for Fatigue Load Alleviation of wind and tidal turbines

Introduction

Unsteady loads are one of the main cause of failures in wind and tidal turbines. Therefore, it is essential to understand how to mitigate these loads to help manufacturers to design blades capable of withstanding a longer life, which will ultimately reduce the levellised cost of energy for energy production. Trailing edge flaps, whether with a rigid or a compliant structure are indicated as the most promising load control system, with performances comparable to individual pitch control [1,2]. These devices allow for a local, distributed control action over the blade and are preferred for their simplicity and inherent reliability.

Methodology

The blade and the passive control system are modelled and analysed using a range of complementary techniques:

1. A low-order code based on blade element momentum theory and linear unsteady aerodynamics. The morphing blades are optimised to minimise the load fluctuations without affecting the mean power harvested.
2. CFD simulations are used to validate the 2D analytical model and to gain further insights on the underlying fluid mechanics (Fig. 1).
3. Experimental tests are performed on extruded 2D models, which have the optimal flexibility identified with the low-order code.

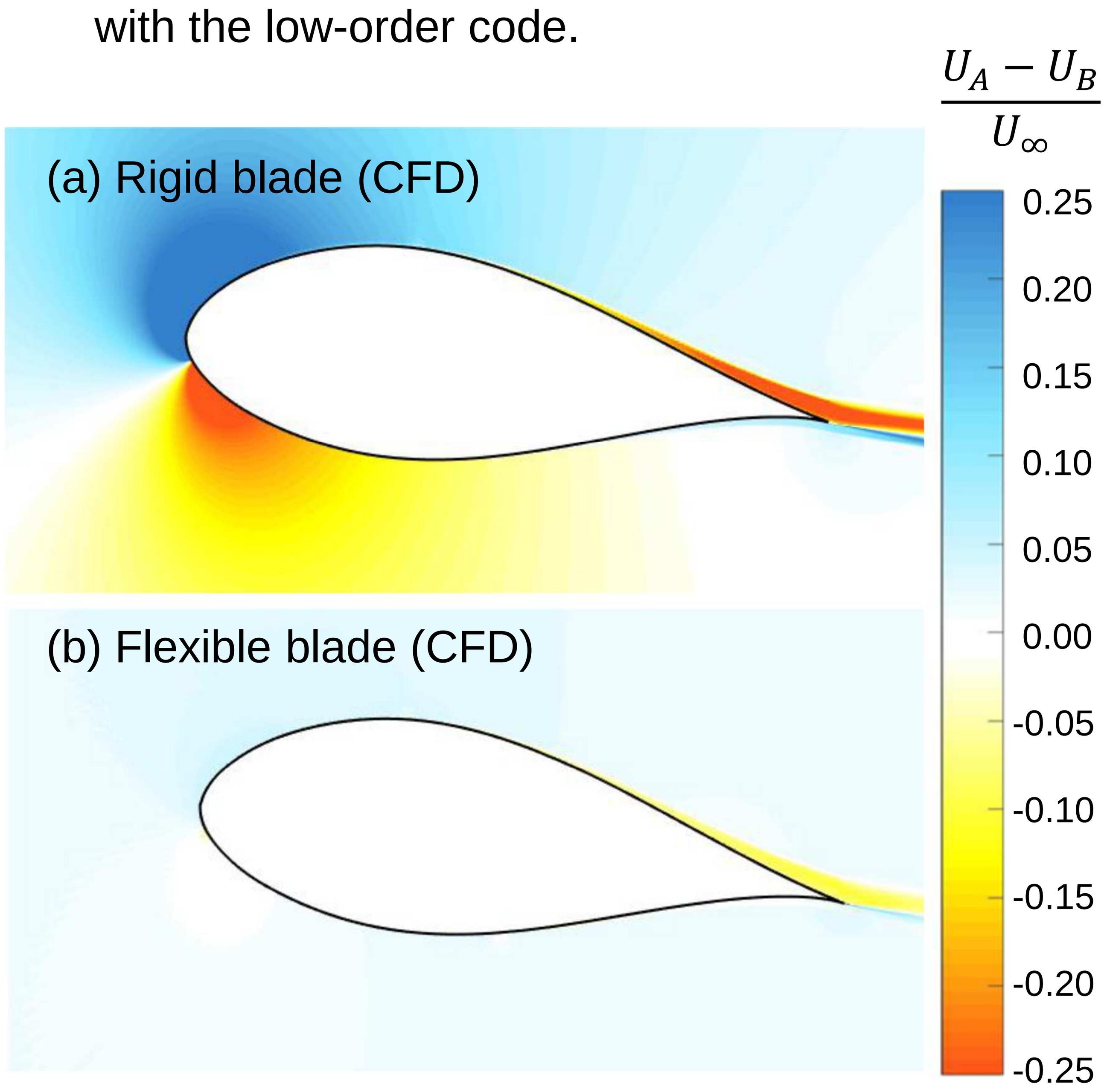

Figure 1 – CFD-computed velocity fluctuations for (a) rigid blade and (b) flexible blade.

Passive Load Control

SRI International manufactures a novel composite smart material that changes its flexibility upon the action of an electrostatic force. Composite laminates are clamped together by applying voltage. Releasing the charge unclamps the laminates, resulting in a change in the elastic modulus of 3 orders of magnitude. The properties of the material are modelled by a mass-damper-spring system which governs the trailing edge angle of the blade. The system is optimised to minimise the load fluctuations on the blade without compromising the power generated. We consider two physical scenarios: (1) a flexible trailing edge, where flexibility is independently optimised for every section along the span of the blade, and (2) a rigid trailing edge connected to the blade by an optimal spring, which minimises the root bending moment fluctuation (Fig. 2).

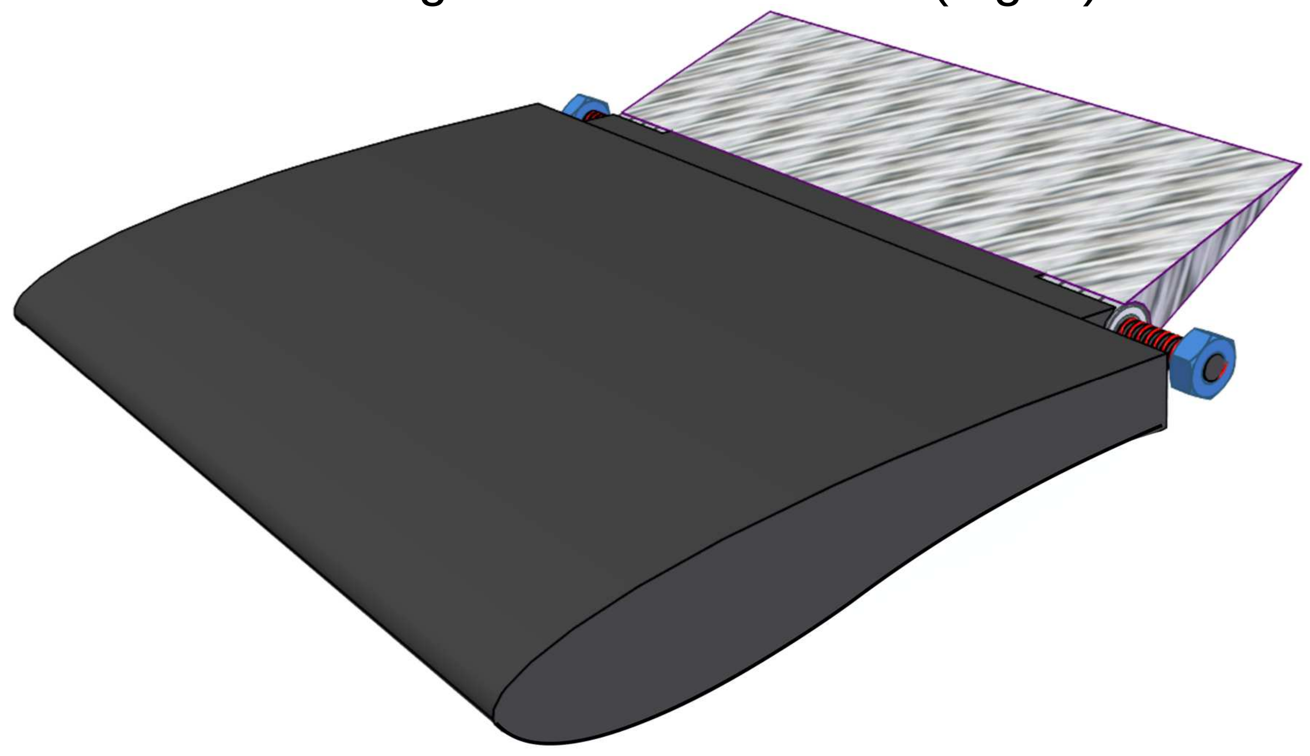

Figure 2 – CAD drawing of the morphing blade tested in a water channel.

Results

The proposed morphing blade allows to cancel the fluctuations of the thrust coefficient almost completely whilst keeping constant the power extracted.

Figure 3 shows that the rotor thrust imbalance, due to the shear in the onset flow, is compensated by the optimal tune of the torsional spring connecting the trailing edge. The average power produced is kept constant.

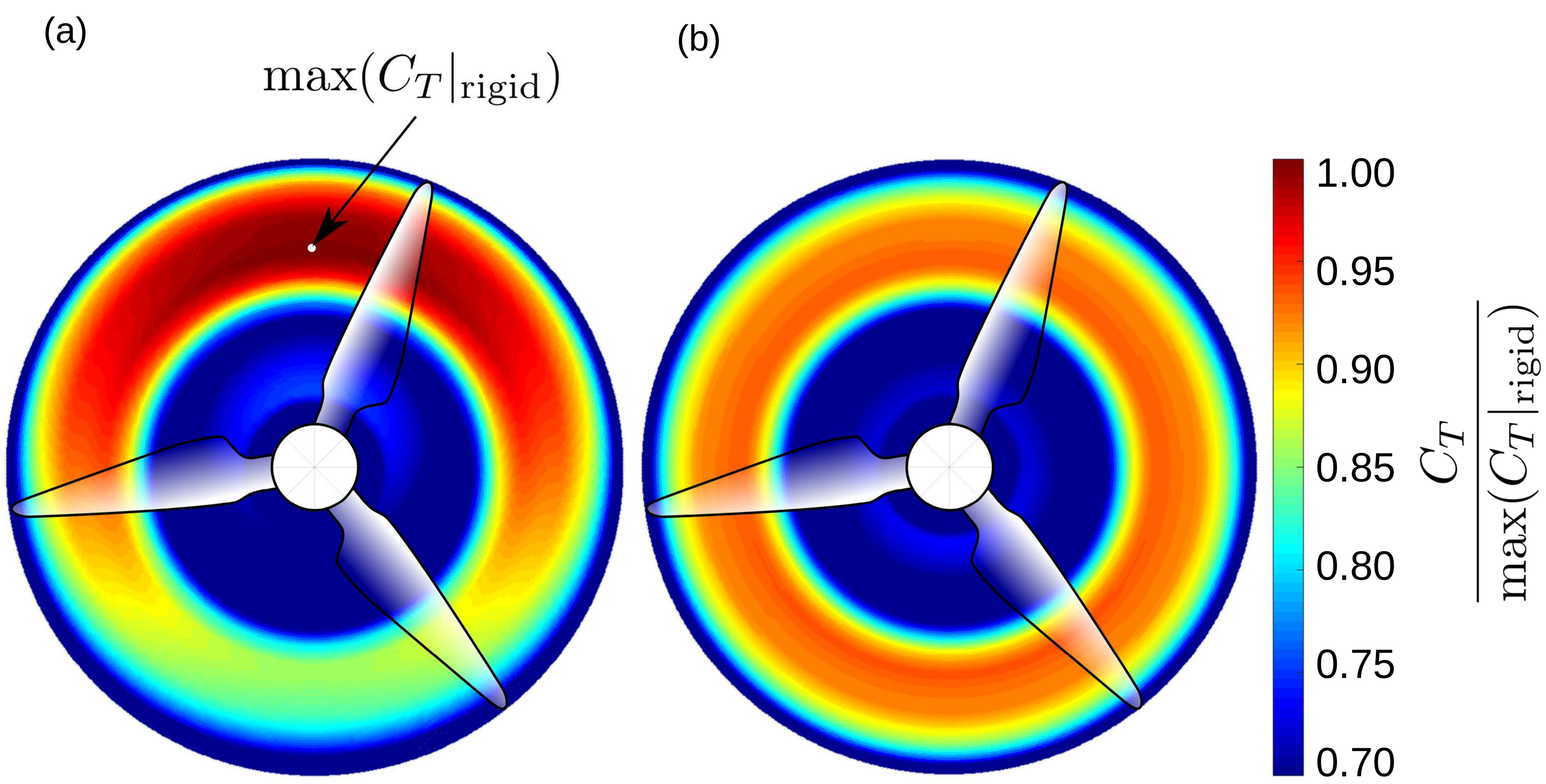

Figure 3 – Distribution of the normalised thrust coefficient for the turbine with (a) rigid blades and (b) morphing blades.

References

1. Barlas, T.K. and van Kuik, G.A.M. (2010), "Review of state of the art in smart rotor control research for wind turbines", Progress in Aerospace Sciences, Vol. 46, pp. 1-27.
2. Lachenal, X.S., Daynes, P.M. and Weaver, (2013), "Review of morphing concepts and materials for wind turbine blade applications", Wind Energy, Vol. 16 No. 2, pp. 283-307.
3. Tully, S. and Viola, I.M. (2016), "Reducing the wave induced loading of tidal turbine blades through the use of a flexible blade", ISROMAC 2016, 10-15 April, Honolulu, Hawaii, p. 9.

THE UNIVERSITY of EDINBURGH
UNIVERSITY OF CAMBRIDGE
NOVA INNOVATION
SRI International

Abel Arredondo-Galeana[a], Weidong Dai[a], Gabriele Pisetta[a]
Dr. Anna Young[b], Dr. Ignazio Maria Viola[a]

a) School of Engineering, the University of Edinburgh, United Kingdom
b) School of Engineering, the University of Cambridge, United Kingdom
For further information, contact I.M.Viola@ed.ac.uk