Morphing blades for passive load control of a tidal turbine

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1. Motivation

Axial-flow horizontal-axis tidal turbine experience significant load fluctuations due to the inherent unsteadiness of the flow. Therefore, it is essential to understand how to mitigate fatigue loads to help manufacturers to design blades capable of withstanding a longer life, which will ultimately reduce the levelised cost of energy for tidal 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. They have low weight and power requirements, a great aerodynamic efficiency and allow for high frequency control authority. Moreover, passive load control devices are preferred for their simplicity as they do not require additional components, thereby helping to further improve the reliability of tidal turbines.

2. Morphing blade model

A passive morphing blade works by aligning part of its structure in the direction of the flow, similar to a wind vane. If the angle of attack increases due to fluctuations of the fluid flow, the blade is bent upwards and its camber is reduced (**Fig. 1**). The effective angle of attack is thus reduced and the loads are alleviated.

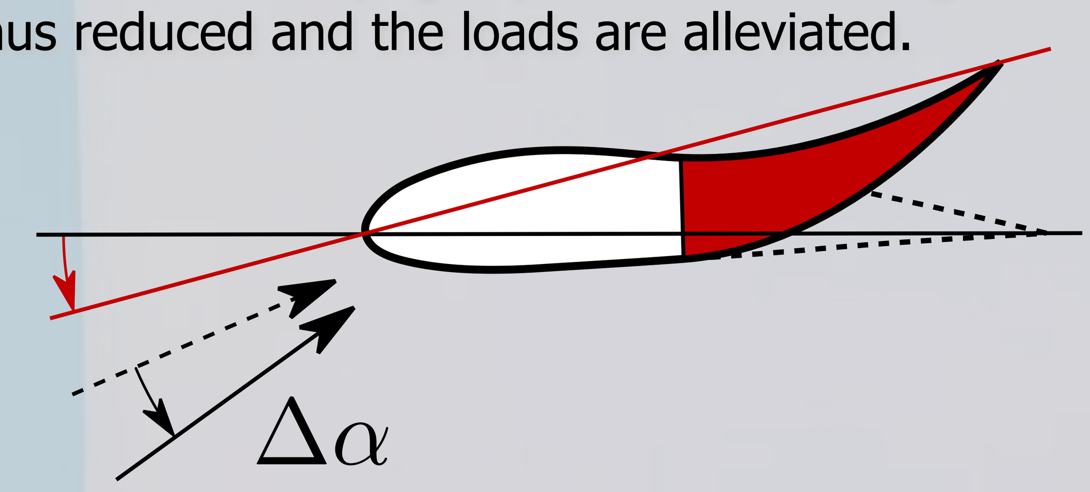

Fig. 1 – Passive morphing blade.

We present a novel morphing blade design that represents the blade flexibility using a torsional spring of stiffness κ (**Fig. 2**). The blade is considered rigid and the spring controls its angular position. Hence, the change in camber is represented by a change in the actual angle of attack caused by the passive pitching of the blade.

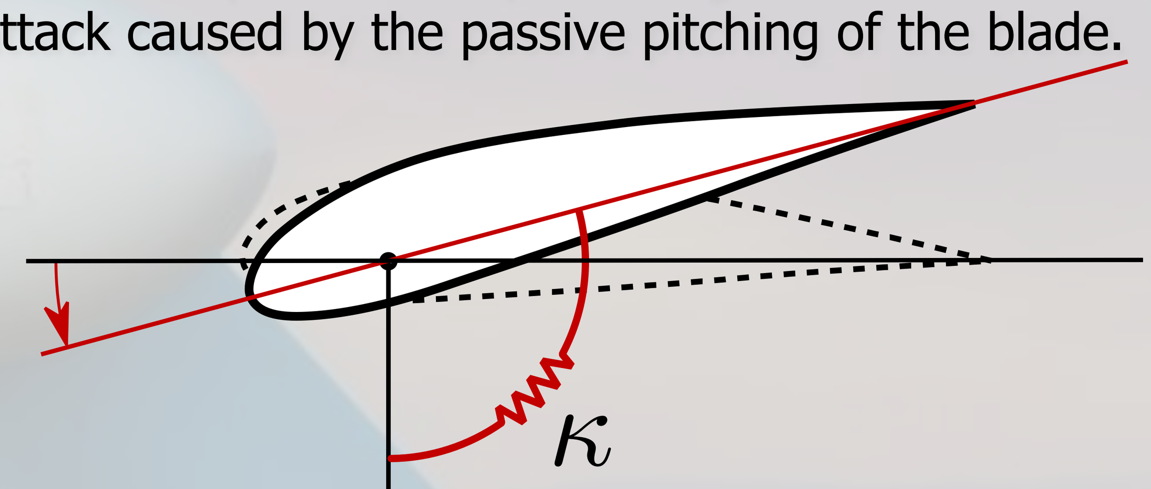

Fig. 2 – Equivalent model of a morphing blade.

3. Methodology

The blade and the passive control system are analysed using a low-order code based on blade element momentum theory. A shear flow causes periodic oscillations of the loads on the blades.

2D flexible foil. Each section moves independently. In the frame of quasi-steady analysis, a spring is tuned to minimise the fluctuations of the local thrust coefficient.

3D morphing blade. All the blade sections move together and the blade deflection is represented by a rigid pitch rotation. The spring is mounted at the root to alleviate the root bending moment fluctuations caused by the quasi-steady loads. The analysis is then extended to consider the dynamics of the blade and the influence of unsteady hydrodynamics.

4. Results

A morphing blade modelled as a passive pitch system is capable of almost complete alleviation of the load fluctuations due to operating the turbine in a shear flow, without compromising the average power generated.

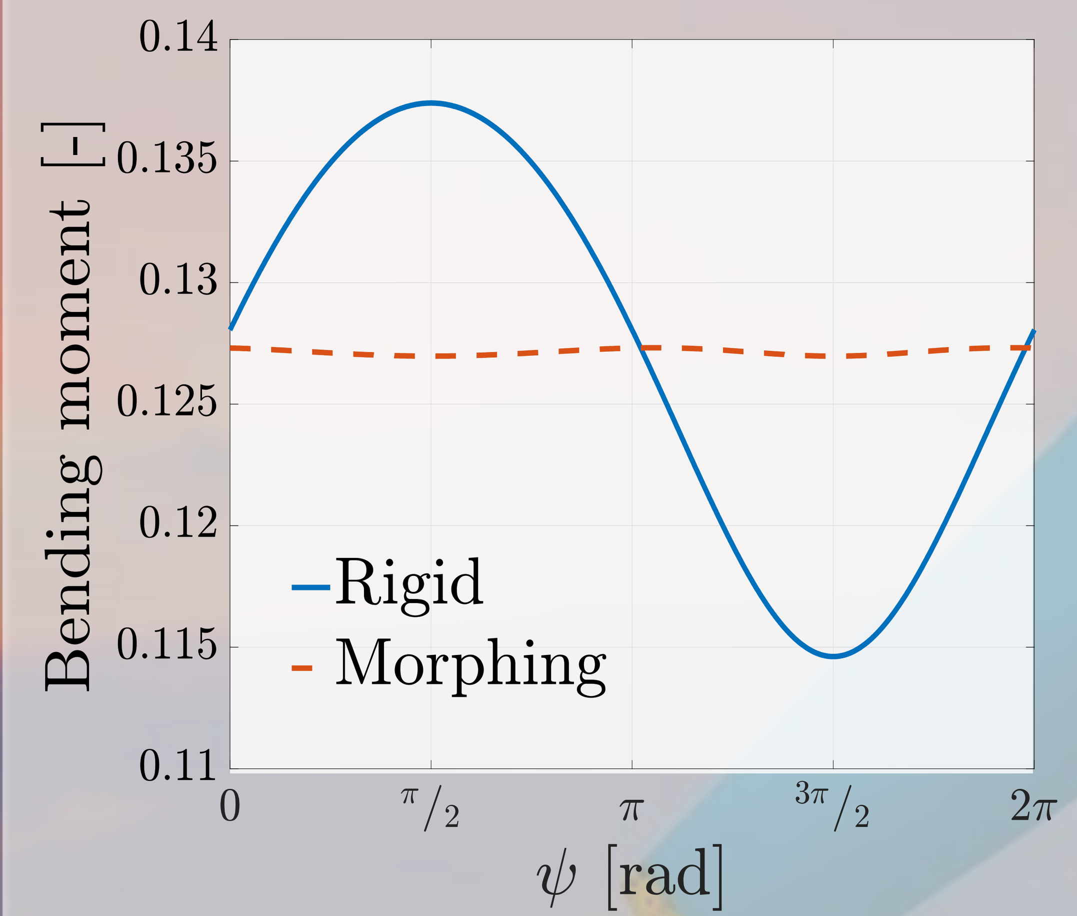

Fig. 4 – Fluctuations of the blade root bending moment..

In particular, in the frame of a 2D analysis, the fluctuations of the local thrust coefficient acting on a blade section are completely cancelled, whilst the average power remains unaffected.

Fig. 3. The rotor thrust imbalance is compensated for a 3D blade controlled by a torsional spring located at the root, between the blade and the hub. The average power generated is kept constant.

Fig. 3. The blade root bending moment fluctuations are reduced by 98%. When considering the unsteady hydrodynamic effects, the fluctuations of the blade root bending moment are reduced by 80%

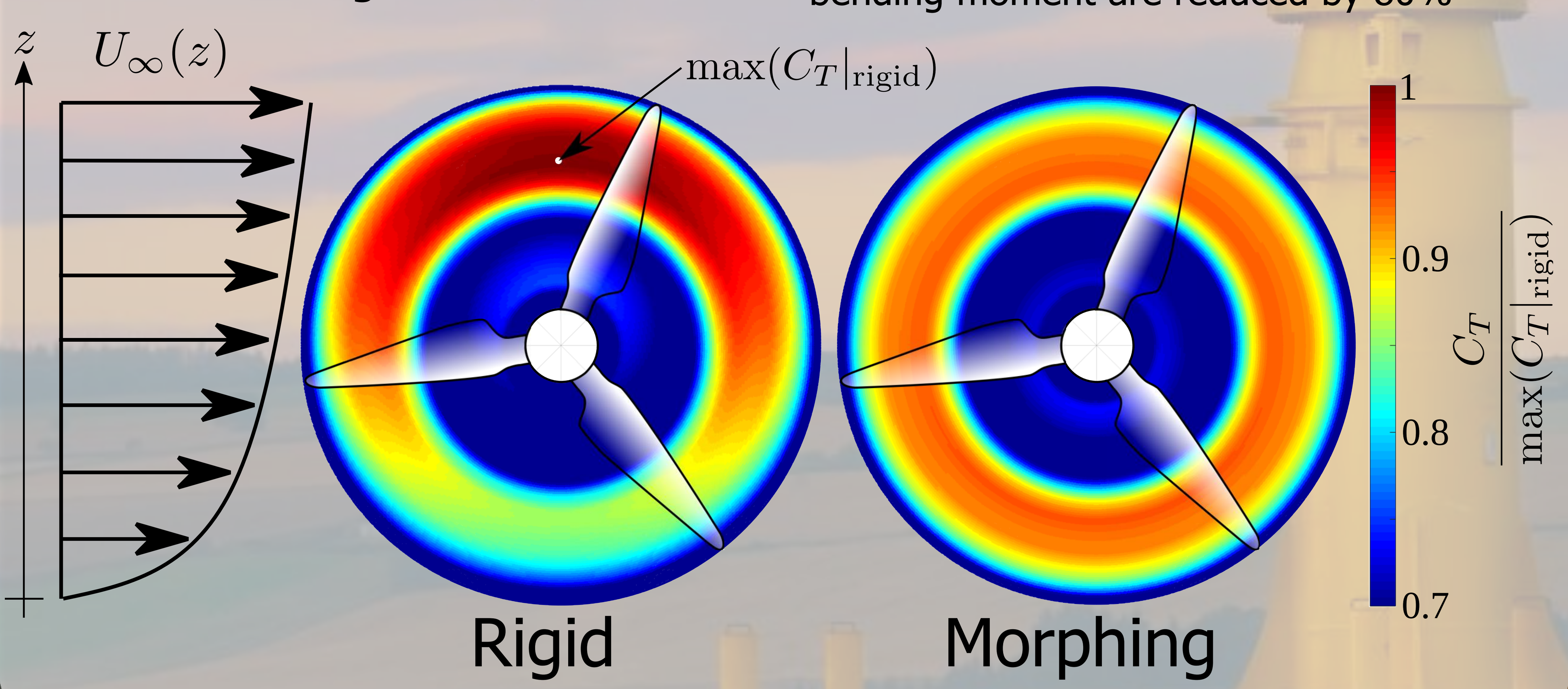

Fig. 3 – Thrust over the turbine rotor.

5. Conclusion

The morphing blade concept represented by a lumped flexibility model is capable of alleviating the fatigue loads experienced by a turbine in a shear flow. A torsional spring was optimised in a quasi- steady analysis to reduce the blade root bending moment fluctuations by 99%. The unsteady analysis showed a reduction of 93%.

6. References

1. Barlas, T. K., & Van Kuik, G. A. M. (2010). Review of state of the art in smart rotor control research for wind turbines.
2. Lachenal, X., Daynes, S., & Weaver, P. M. (2013). Review of morphing concepts and materials for wind turbine blade applications.

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