

*Multi-MW reference kite developed by TU Delft, DTU and ETH Zurich
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Aeroservoelastic Analysis and Optimization Framework for Morphing AWE Wings

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Morphing wing AWE aircraft based on compliant internal structures – compared to aircraft equipped with discrete wing control surfaces – show great potential in increasing the power production capabilities of AWE systems [1]. Potential benefits of morphing wings range from greater adaptability to different flight conditions to reducing the drag – and therefore increasing the power harvesting factor – due to the smooth wing surface. Furthermore, a reduction in parts count and complexity can be achieved, especially when applying novel additive manufacturing techniques. The greatest challenge in applying morphing to AWE are the contradicting requirements of high stiffness and strength to withstand the aerodynamic loads, while simultaneously maintaining compliance to allow for the desired shape adaptation. Therefore, it is of great importance in the design of morphing wings to consider the full system dynamics from an early stage.

In this work, a design methodology is presented that allows to concurrently analyze and optimize the control, structural, and aerodynamic design parameters of an AWE morphing aircraft. The numerical model presented in this work couples a dynamic system model, consisting of a ground station, tether, and aircraft dynamics model, with a two-way fluid structure interaction (FSI) simulation of the wing [2]. The FSI model consists of a detailed 3-D finite element model to assess the structural behavior, coupled with a 3-D panel method to calculate the aerodynamic characteristics of the wing.

To increase the computational efficiency of the simulation, reduced order modelling (ROM) techniques are applied to the structural and aerodynamic model of the wing. The structural ROM relies on a mode superposi-

tion method, whereas the aerodynamic model relies on a Taylor-expansion of the aerodynamic influence coefficient matrix in the direction of the structural modes. The Taylor-expansion can be efficiently computed using the Sherman-Morrison. This allows the ROM to deliver speed-up factors of about 180, when compared to the full simulation, at virtually no decrease in accuracy. The ROM is coupled to the dynamic system model and a flight controller consisting of an aircraft and ground station controller is included in the dynamic simulation, enabling the tethered aircraft to follow predefined trajectories.

To identify the optimal system parameters, the introduced dynamic model is embedded in a genetic optimization framework [3]. With the proposed framework, optimizations can be performed, maximizing the power production capabilities of morphing AWE aircraft. Furthermore, the framework is not limited to morphing wings, but can also be used for the design and optimization of conventionally actuated AWE aircraft of arbitrary size, with arbitrary flight trajectories and control strategies.

References:

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- [2] Fasel, U., Tiso, P., Keidel, D., Molinari, G., and Ermanni, P., “Reduced Order Dynamic Model of a Morphing Airborne Wind Energy Aircraft,” *AIAA Journal*, 2019.
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