Dynamic Model of a Bridled Kite Including Rotational Deformations

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This study describes a dynamic model of a kite as a main component of an Airborne Wind Energy system for cross-wind operation. The generated power depends largely on the actively controlled flight path of the kite [1] which is why a fast and accurate dynamic model is of vital importance for optimising the governing control algorithms. The model includes basic rotational deformations of the wing (torsion and bending) while being real-time capable for control purposes. It was built in SimMechanics [2] and consists of three rigid plates, interconnected by gimbal joints, which allow for three rotational degrees of freedom (RDoF) per joint (plate intersections physically ignored), as shown in the left figure. To model flexibility, a spring and a damper were associated with each RDoF. A body-fixed coordinate system was defined for each plate to determine local apparent wind velocity and corresponding aerodynamic lift and drag forces. Apparent (centrifugal/coriolis) and gravity forces were implicitly defined in a so-called machine environment. Realistic steering was accomplished through rigid steering lines of variable length, attached to a Kite Control Unit (KCU). The front (power) lines were kept at constant length. The atmospheric wind model (without turbulence) and aerodynamic characteristics were taken from an existing 4-point-mass model [3]. The basic tether model consists of two point masses (2RDoF universal joints between tether segments) and is shown in the right figure. Reeling out or in at constant speed is implemented.

A robust kite model was developed carrying realistic steering, the simulations reproduce the main deformation modes (bending/torsion) and have the potential to run real-time, making the model suitable for control simulation purposes. The kite was steered into eight-figure trajectories, using a planned trajectory and a controller algorithm for the tracking error [1]. Results for angle of attack, traction force and flight velocity were validated by simulation results of a 4-point-mass model (which in turn has been validated against measurement results [3]) carrying the same dimensions, through optimisation of the spring constants in the gimbal joints connecting the kite plates.

References: