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Multiple-Wake Vortex Lattice Method for Airborne Wind Energy Membrane-Wing Kites

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A suitable wing design for pumping kite power generation is the leading edge inflfated (LEI) tube kite because the bridling and leading edge design allow the wing to be depowered while retaining good steerability. Current LEI kite design is typically empirical. Fluid-Structure Interaction (FSI) modelling is necessary to decrease design time and gain insight into the physical processes driving kite performance.

Unfortunately, the current kite aerodynamic models do not meet the requirements for LEI tube kite FSI modelling: they are either fast but insufficiently accurate, or accurate but computationally expensive. In particular, the current fast aerodynamic models are not able to represent the effects of the multiple flow separation regions – such as behind the LEI tube and above the canopy's trailing edge – inherent to an LEI tube kite flying at a large range of angles of attack.

It is well established that 2D multiple wake vortex models can model multiple separation regions over membranes. Consequently, it is probable that a multiple-wake vortex lattice method (VLM_{MW}) could model the multiple separation regions expected on a 3D membrane-wing surf-kite. To the author's present knowledge, no such VLM_{MW} aerodynamic model has yet been constructed for 3D membrane-flow problems.

This ongoing M.Sc. thesis is intended to evaluate the hypothesis that a quasi-steady multiple-wake vortex lattice method can quickly and accurately model surf-kite aerodynamics to generate aerodynamic surface load distributions.

This VLM_{MW} models the vorticity generation in the flow with multiple vortex lattices shed from the separation locations, as well as the standard bound vortex lattice. The separation locations are fixed at known locations. The impermeability boundary conditions allow for membrane deformation such that the model can be used for FSI functions. The figure shows the multiple-wake layout of the flow model.

The lift and drag polars generated for arc-shaped wings with a single-wake model have been validated for a Clark-Y airfoil arc-shaped paraglider, as well as the Mutiny "V2" kite of TU Delft.