TU Delft team launching a Genetrix kite on the Maasvlakte2, The Netherlands (22 June 2012).

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KitePower

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Flight Path Planning in a Turbulent Wind Environment

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Converting the traction power of kites into electricity can be a low-cost solution for wind energy. Kite power systems in pumping mode of operation harvest wind energy by reeling out the tether at high force with the kite flying cross-wind manoeuvres and reeling in at low force with depowered kite. Optimising the flight manoeuvres is crucial to achieve a high system efficiency and robust control at varying wind conditions. Sophisticated methods for the optimisation of a closed pumping cycle, combining reel-in and reel-out in a single figure-of-eight, exist [1] but these have not yet been demonstrated for an implemented prototype. Therefore, we developed a flight path planner, that uses a list of attractor points and turn actions for the planning process. The coordinates are calculated using simple, explicit geometric formulas. The path can be adapted to the average wind speed and the vertical wind profile. A small set of parameters is used to modify the flight path and to tune it to achieve optimal results. The planner uses a finite state machine with switch conditions that are highly robust for sensor errors. The performance is verified with a dynamic kite power system model [2]. It is operated in environmental conditions using wind data from the 213 m high KNMI-mast in Cabauw, Netherlands. The turbulence model uses a precalculated 3D wind field according to the Mann model [3]. The performance was evaluated for a maximal heights of 300 and 600 m, which correspond to average heights during reel-out of 98.7 and 197.4 m. The results show, that the decline of the average power output of pumping kite power systems at high wind speeds can be significantly mitigated using the proposed planning algorithm. In addition it is shown, that reeling out towards zenith after flying figures of eight significantly reduces the reel-in forces and thus increases the total efficiency. Using the potential energy of the kite as a storage for parts of the needed reel-in energy further increases the overall efficiency.

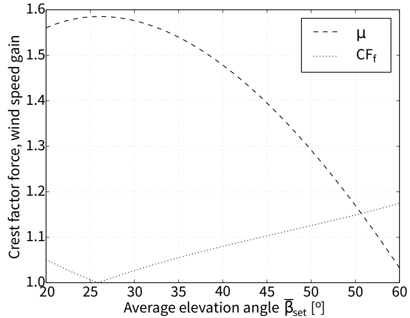

Figure: Nondimensional wind speed gain μ and crest factor of the tether force CF_f as function of the average elevation angle offset. Tether length l_t = 300m and α = 0.234 approximated for Cabauw.

References:
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[3] Mann J.: Wind field simulation. Probabilistic Engineering Mechanics, Vol. 13, No. 4, 269–282 (1998)