Roger J. Coenen

MSc Student
Delft University of Technology
Faculty of Aerospace Engineering

Laan 28
2512 GN Den Haag
The Netherlands

rjcoenen@hotmail.com
lr.tudelft.nl

Design of a Lightweight and Durable Kite for Cost-Effective Traction Power Generation in a Pumping Kite Power System

Roger J. Coenen, Sil Drenth, Tommy Smits, Marijn L. W. Veraart
Faculty of Aerospace Engineering, Delft University of Technology

This presentation focusses on a design exercise for a pumping kite system. In recent years most research has been dedicated to inflatable kites for a pumping kite power generation system. As the technology matures, these inflatable kites now show their limitations in terms of durability, scalability, aerodynamic performance and therefore overall power generating performance.

The challenge was to design a lightweight yet strong, stable yet agile and high performance yet low cost kite. The system was designed for a continuous traction phase power of 40 kW (between 200 to 700 m of tether length) at a ground-based (6 m) wind speed of 5 m/s up to 12 m/s and to remain operable up to 25 m/s. The trade-off criteria were primarily costs, stall speed, retraction phase power and design risk.

The kite was sized for the 40 kW traction power requirement at low wind speeds. This resulted in a kite with a 12.7 m^2 main wing and a (limited) span of 10 m. The kite is fully built from carbon-fiber-reinforced polymer (CFRP). The structure was designed for a maximum traction load of 20 kN with a safety factor of two. The main wing is partly designed as a sandwich structured wing box to counter buckling. The traction tether is split into a two-line bridle attached to the wing in such a way that the bottom skin is only loaded in tension. This eliminated the need for sandwich structure in the bottom wing box panel. It has an inverted T-tail connected to the wing with an upward swept tail boom to reduce drag at high angles of attack. This resulted in a kite of only 40 kg. The kite has ailerons, a rudder and an elevator and is therefore fully stable and controllable, even when the tether is disconnected. The bridle split has a pulley for free roll movability. On-board power is generated using a small turbine. The flight computer is situated in the ground station and is linked to the kite by a wireless communications link system. For the aerodynamic analysis, XFLR5 was used and for the structure, thin-walled beam stress analysis in combination with von Mises-stress analysis and curved-plate buckling analysis were used.

The power production performance was analysed using a Weibull wind speed distribution and optimised cycle output for every wind speed. It was then compared to a conventional 40 kW rated power wind turbine. With a yearly average of 22.6 kW the kite proved to produce 8% more energy per annum, at a fraction of the material usage. The main structural components of the kite are expected to have a lifetime of 5 years. The tether would need replacement two times per year. With a levelelised cost of energy (LCOE) of 0.113 €/kWh (75% of PV solar) a return on investment of 9.8% would be achieved. Upscaling of the kite to a minimum of 100 kW average power output, would drive the required LCOE down. Design choices and trade-off will be elaborated more on in the poster.