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The Second, Most Important, Law of Tether Scaling

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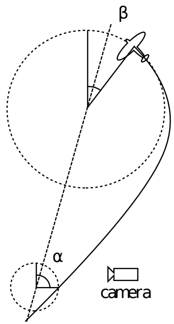
We will present a differential equation describing the tether as a curve in 3D space along the length of the tether. Compared to simpler models, it gives more fidelity. Compared to piecewise stiff tether simulations it is easier to reason about and is calculated quickly.

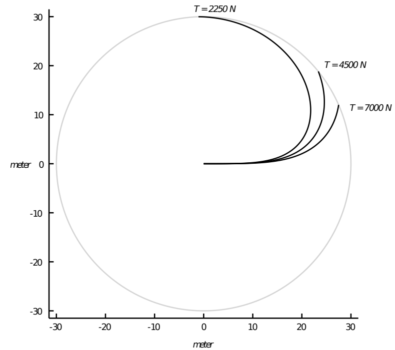
By using this equation, we arrive at 'the second law of tether scaling'. The tether length is not only limited by tether drag but also tether mass. The law states that a minimum tension is given by:

$$T > \mu \left(\frac{vl}{R} \right)^2$$

where T is tether tension, l is the length, μ is the weight per meter, v and R is the flying speed and looping radius of the kite.



We have done experiments using an in-situ method of estimating the tether drag coefficient by measuring the phase difference of the tether at the winch and the kite looping. This showed preliminary results close to the expected value $C_{(D,t)} \approx 1.1$ [1].



Numeric solutions of tether shape for a looping kite looking from the winch along the centerline. The curves show different tether tensions, for tether length 400 m, diameter 4 mm, looping radius 30 m and kite speed 40 m/s. Note 4500 N is approximately according to 'the second law'.

References:

[1] Dunker S.: Tether and Bridle Line Drag in Airborne Wind Energy Applications. In: Schmehl R. (eds) Airborne Wind Energy. Green Energy and Technology. Springer, Singapore pp.29–56 (2018). https://doi.org/10.1007/978-981-10-1947-0_2