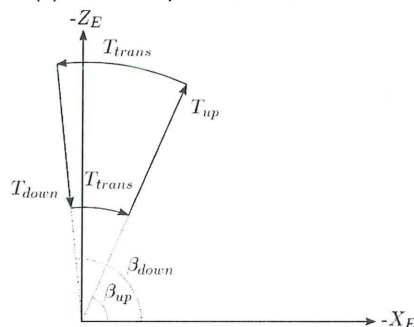


## 1 Basic fluid dynamics

- (a) What is the definition of Wind Power Density (WPD)?
- (b) Explain the mechanism of the Magnus effect.

## 2 Wind turbine and kite power system

- (a) Draw the velocity diagrams for
  - (i) a wind turbine rotor blade (at high tip speed ratio).
  - (ii) a kite operated in a conventional (non-cross wind) pumping cycle as indicated in the figure



Consider only the energy extracting reel-out phase (up) and the energy consuming reel-in phase (down) by drawing two separate velocity diagrams.

- (iii) a kite operated in pure cross wind mode (tether velocity and true wind velocity aligned).
- You may draw 2-dimensional cross sections of rotor blade and kite wing.
- (b) Explain the aerodynamic similarities and dissimilarities of wind turbine and kite power system.

## 3 Vorticity

In potential flow theory lifting surfaces can be represented by bound vorticity. In 3-dimensional flows such bound vorticity is (almost) always accompanied by shed and/or trailing vorticity left in the wake of the lift generating surface. Explain, what characteristic of vorticity is related to energy extraction, and what characteristic of vorticity is only related to energy losses. Explain why.

## 4 Properties and modeling of wind

- (a) Explain shortly what a Hadley cell is.
- (b) How do you characterize a neutral atmospheric boundary layer?
- (c) Explain what rotational sampling is for a wind turbine operating in a turbulent wind field.

## 5 Design of a kite power system

- (a) Should energy generating kites be designed for maximum thrust (thug force) or for optimal thrust? (think about trade off between lift and movement in the direction of the wind and give an explanation of your answer).
- (b) What is the optimal reel-out speed of a kite (optimal with respect to maximum instantaneous power generation)? Explain why.

## 6 Induced drag

- (a) Explain what induced drag is for a wing operating in parallel flow.
- (b) Induced drag also plays a role in wind turbines and kites.

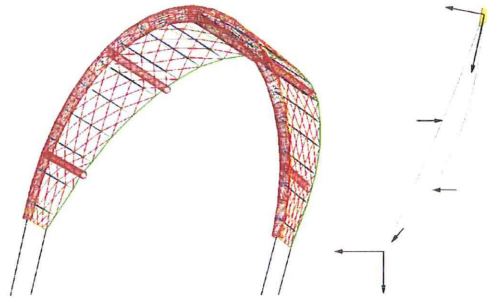
Answer the following questions:

Should induced drag be minimized for optimal performance of

- wind turbine rotor blades
  - (single) energy extracting kites
- and explain your answers.

## 7 Flight dynamics of kites

- (a) Explain shortly the fundamental mechanism of steering an arc-shaped kite around sharp turns. What is the contribution of flexibility in this mechanism?



- (b) Explain why a kite is particularly prone to collapse and crash during the reel-in phase during which the kite is depowered?

