Wind Turbines With Flexible Blades In The Steady Regime

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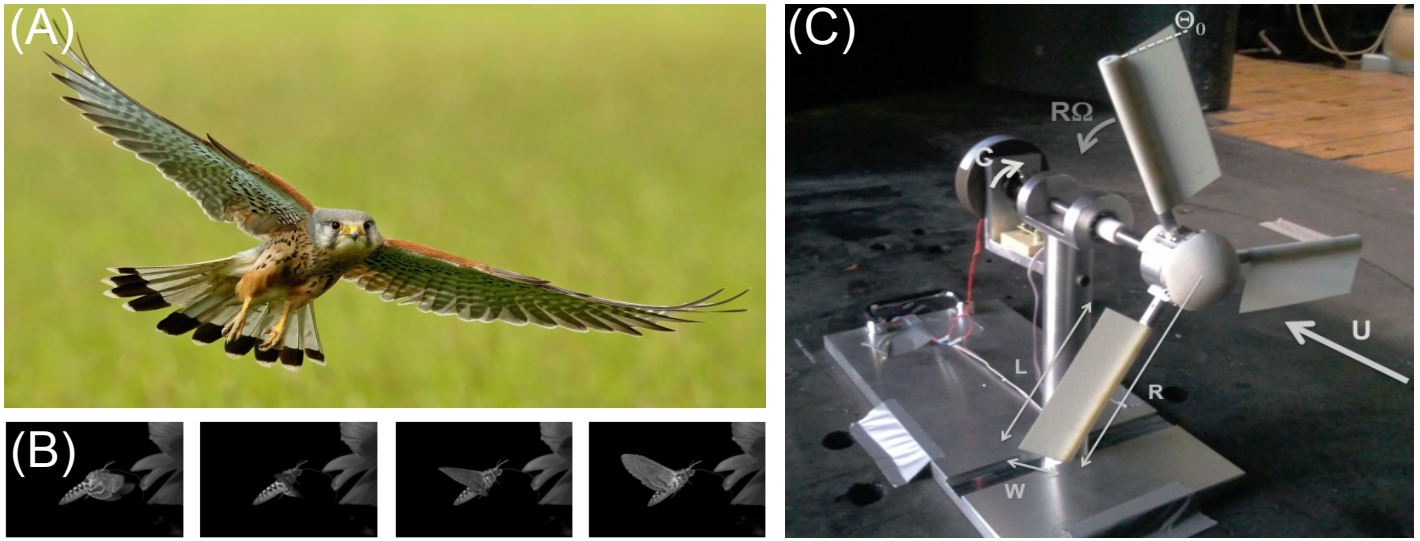
Current wind turbines are designed to work at a specific wind velocity. Besides flexible wings have been shown to improve the flight performance of birds and insects *(1),* and leaves decrease the drag by bending *(2).*
What if we allow the blades of a wind turbine to be flexible spanwise ?

We present here experimental results about a small wind turbine in the steady regime showing how the flexibility of the blades governs the performances.



(A) Eagles and (B) butterfly have flexible wings which enhanced their flight's efficiency. (C) Experimental setup : the small experimental wind turbine in the wind tunnel (ENSAM Paris) and the parameters.

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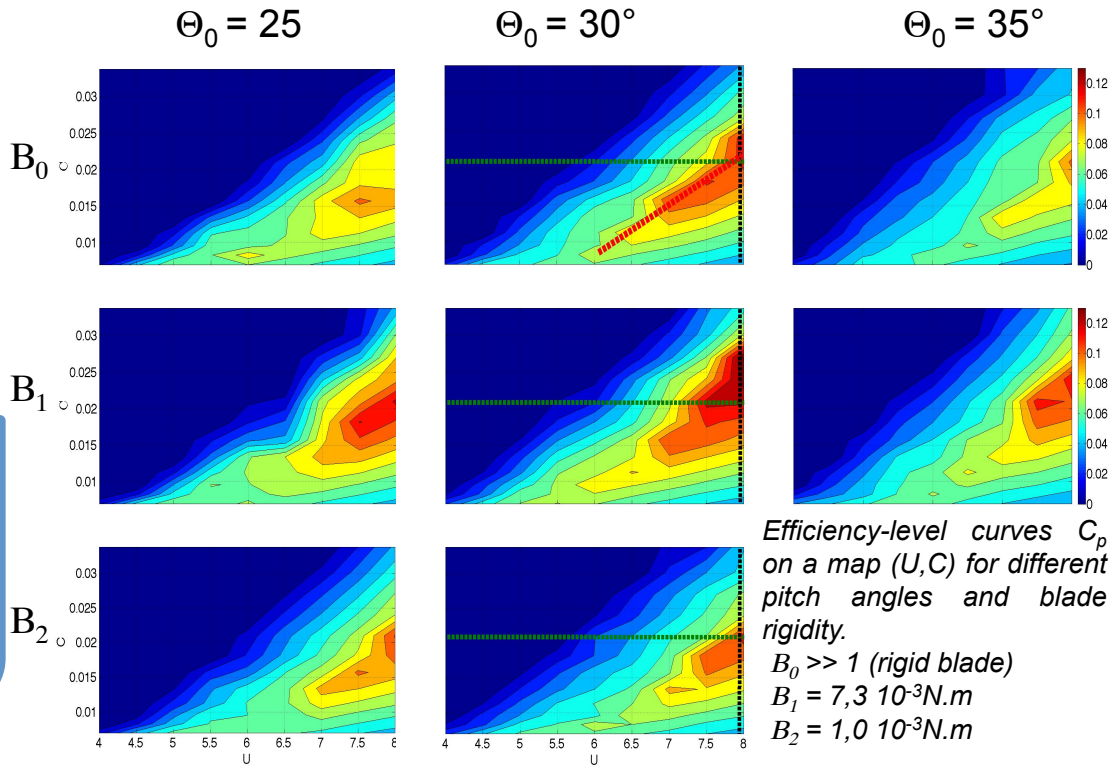
1) Experimental results

- ***U*** : Wind velocity (from 4 to 8 m/s)
- ***C*** : Resisting torque (from 0.007 to 0.034N.m)
- Θ_0 : Pitch angle (from 0 to 35°)
- ***B*** : Bending modulus of the blade (from 1.0 10^{-3}N.m to rigid).

$$\lambda = \frac{R\Omega}{U} \quad ; \quad Cp = \frac{P_{collected}}{P_{wind}} = \frac{C\Omega}{\frac{\rho}{2}U^3 S}$$

⇒ Experimental results show :

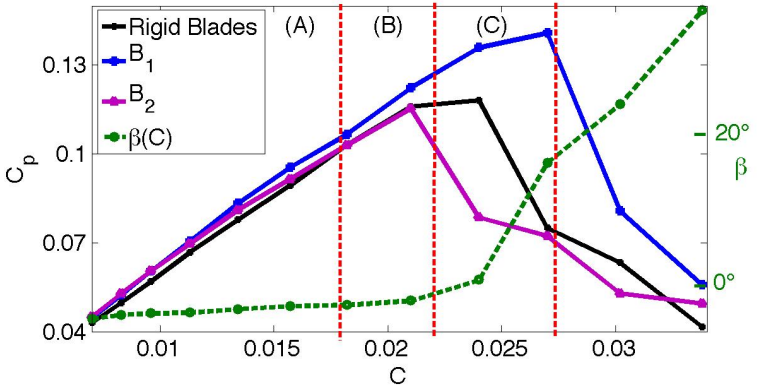
1) An **optimum of performance with respect to the bending modulus** (vertical reading)
2) **The lower B, the larger the operating range** (as long as the deformation of the blade is not too big)
3) An optimum of efficiency with respect to the pitch angle (horizontal reading). $\Theta_0^{optimal}$ = 30° for rigid and flexible blades.

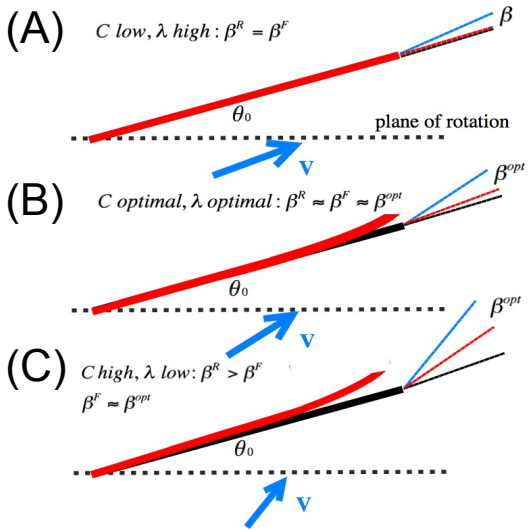


Efficiency-level curves C_p on a map (U,C) for different pitch angles and blade rigidity.
B_0 >> 1 (rigid blade)
B_1 = 7,3 10^{-3}N.m
B_2 = 1,0 10^{-3}N.m

2) The role of β

β is the angle between the total wind velocity *V* and the blade. For a rigid blade : $\beta = ArcTan(1/\lambda) - \Theta_0$





Flexible blades with an accurate bending modulus can passively bend before stall to enlarge the optimal efficiency range.

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