Barotrauma in bats due to wind turbines.

Student Workshop - University of Witwatersrand

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Opening Comments

- There is a rapid, global push for wind energy installation.
- It is a major source of renewable energy to combat climate change.
- Australia already has a number of wind farms and many more are proposed.
- They have existed in Europe for many years - many in the ocean, but also many on land.
- They appear to rotate quite slowly, but tip speeds can be very high (up to 300 km/hr)

Collision Risk

- Risk of collision with wildlife has been a major concern for many years, and in most countries an analysis of "Bird collision risk" is essential for Environmental Impact assessment required by most Governments.
- Many birds are killed each year, although data is a little difficult to obtain because the wind farm managers are reluctant to share.
- Existing models of bird strike are "standard" but in my view not particularly good!
- In addition, it has been stated that large numbers of bats are killed by turbines each year, raising concerns about the impacts of wind energy expansion on bat populations.

Bats

- *Barotrauma* refers to damage done by pressure changes.
- There is a lot of evidence of bats dying in the vicinity of wind turbines for energy generation.
- However, it is NOT from direct collisions with the turbine blades.
- There is a lot of evidence that mitigation techniques such as turning the turbine off at low wind speeds is effective in reducing the deaths....
- .... but the actual cause is not known,
- Bats are mammals and have very weak lungs - a sudden pressure change may cause them to suffer internal injuries (baratrauma)

Prevention

- In spite of not knowing WHY, there are successful strategies that have been employed to reduce the death toll in bats.
- Preventing turbine blades from spinning at low wind speeds, referred to as curtailment, is one method successfully used to reduce bat fatalities.
- Drawing consistent inference across multiple studies has been challenging - partly because energy providers may be unwilling to do it and it isn't clear what the results are...
- Increasing the speed at which the turbines are turned off reduced fatalities by 33 % with every 1.0 increase in cut-off wind speed.
- The rationale is that bats are less active in windy conditions.

What can we do? What is the cause?

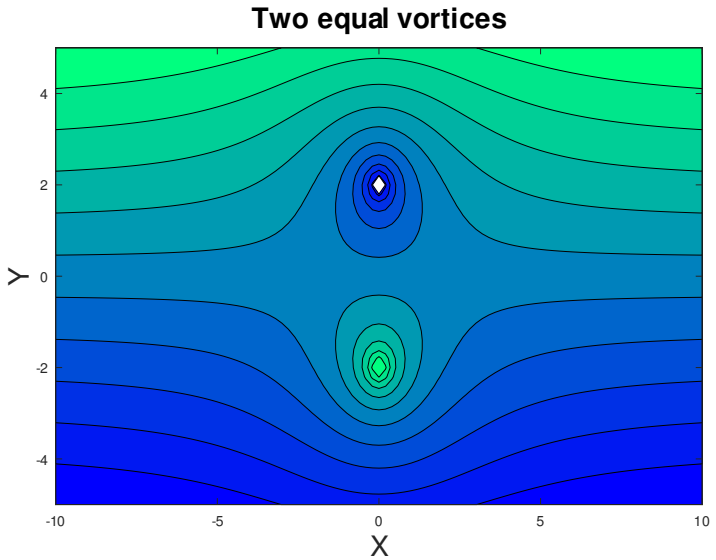
- What is our best approximation to the pressure drop to cause barotrauma?
- Wing-tip vortices - what are they, what pressure differential do they cause?
- Starting vortex - when the blade spins up, there is an initial vortex that spins off the blades.
- Why do the mitigation strategies (curtailment, switching off) work?
- Bats use sonar to see, could it be acoustic pulses from the rotating turbine?
- Is a turbulent wake or a turbulent bursts a possible cause?
- Are there other possible causes?

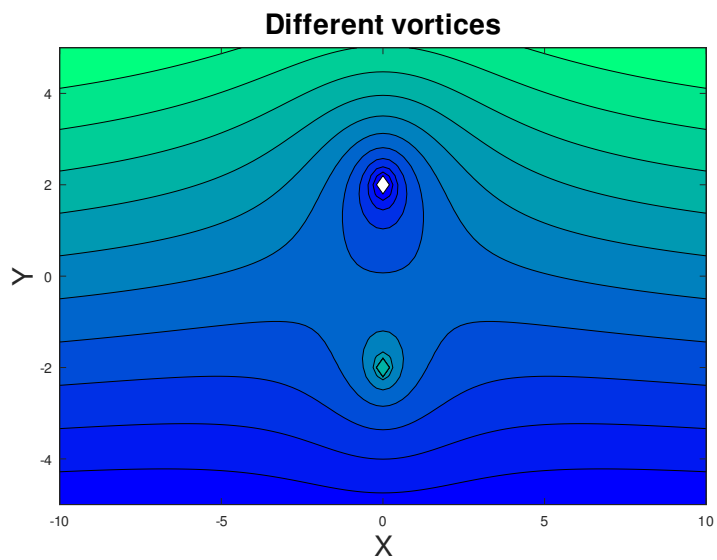
What is a vortex?

- Using complex variables, $f = \phi + i\psi$ is a complex potential.
- The velocity field is then given by $f'(z) = u - iv$ where u=horizontal velocity and v=vertical velocity.
- A vortex flow in a horizontal flow is defined by

$$f(z) = Uz \pm \frac{i\gamma}{2\pi} \log(z - z_V)$$

  where U=stream velocity, γ = vortex strength, z_V is vortex location. The sign indicates the direction of rotation.
- In real flows they often occur in pairs, but can also used (as you will see later) as a mathematical tool because they satisfy Laplace's equation and can be compounded to give other flows.





- If the same strength, they track along parallel
- If different strength, they will end up circing each other!
- Using their velocity fields, can track their movement and intensification.
- In 3 dimensions, airfoils shed a "vortex sheet" (discontinuity) that rolls up, becoming more and more intense.

The problem

- Consider the possible causes of barotrauma in bats.
  - vortex shedding
  - startup vortex
  - turbulent bursts
  - violent sound pulsed
- Evaluate possible mitigation strategies