Physics of turbines translated to the planktonic scale

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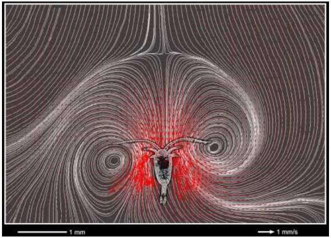
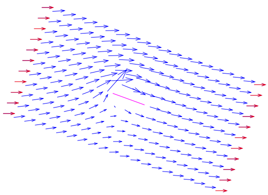
Solid or fluid, it's a matter of scale...

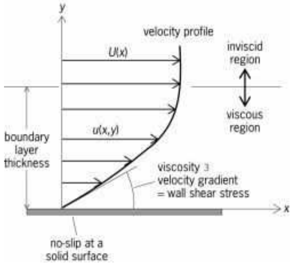
- Ratio of gravitational force to strength of rock
  - Small at a human scale $\rightarrow$ solid
  - Large at a continental scale $\rightarrow$ viscous fluid
- Ratio of inertial force to viscous force
- Reynolds number $R_e = \frac{UL}{\nu}$
  - R_e large at Turbine scale $\rightarrow$ $\sim$inviscid fluid
  - R_e small at plankton scale $\rightarrow$ very viscous
  - **Compare strain of flow due to a zooplankton with strain of flow due to an instream turbine blade**



Scales of hydrofoil mechanics

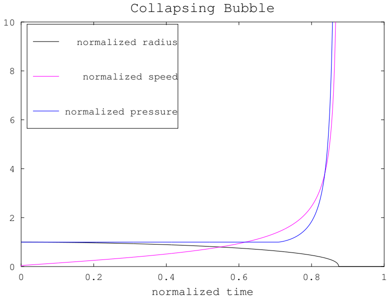
- Inviscid theory (no viscosity) with added large-scale circulation describes most of the current past the blade:
  - Kutta-Joukowski lift theorem
  - **Broaden leading edge**
  - **Little strain in most of the flow past the blade**
- Thin viscous boundary layer at the surface of the blade
  - Boundary layer has higher strain but occupies a small volume → **small portion of plankton will pass through the boundary layer**
  - **Pressure determined by the large-scale inviscid dynamics → not a problem for plankton**
  - Except if there is cavitation . . .





Caviation/Bubbles

- Cavitation: bubbles formed when pressure goes negative
- Collapsing bubbles $\rightarrow$ large pressure (small-scale and short-lived)
- **Cavitation should not happen for well-designed instream turbines that are deployed at sufficient depth**
- **Video and acoustic measurements should be made in order to demonstrate that there is no cavitation**



Big turbines can be better

Power = Pressure $\times$ Area $\times$ Speed

- Hydroelectric dams focus fast flow onto a small Area with huge Pressure and high blade Speed relative to water
- In-stream turbines with lots of Area and low Pressure and small blade Speed relative to water

Safer to get your Power from a turbine that sweeps a big Area with low Pressure and small Speed $\rightarrow$