Innovations Based On Fluid Mechanics

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Innovation is …

"… the **action** or **process** of innovating (making changes in something established by introducing new ideas, products, processes, or services)"

https://languages.oup.com/google-dictionary-en/

"… the **systematic practice** of developing and marketing breakthrough products and services for adoption by customers."

https://www.mckinsey.com/featured-insights/mckinsey-explainers/what-is-innovation

"… the **process** of bringing about new ideas, methods, products, services, or solutions that have a significantly positive impact and value."

https://ideascale.com/blog/what-is-innovation/

"… the **practical implementation** of ideas that result in the introduction of new products/services or the improvement of products/services."

https://en.wikipedia.org/wiki/Innovation

4 Types of Innovations

- **Incremental innovation:** improving existing products/services. Example: going from iPhone 1 to 2, 2 to 3, and so on
- **Adjacent innovation:** creating new products/services related to the company's current products/services. Example: Amazon's expansion into the cloud computing market with Amazon Web Services (AWS).
- **Disruptive innovation** has 2 subtypes
  - **Low-end disruption**: using a low-cost business model to enter at the bottom of an existing market and claiming a segment. Ex. Toyota/GM
  - **New-market disruption**: creating a new segment of underserved customers in an existing market using low-quality and low-cost products and improving quality later. Examples: personal computers and smartphones

https://online.hbs.edu/blog/post/new-market-disruption

4 Types of Innovations

- **Radical innovation:** creating a new product/service that significantly changes or replaces an existing market. Example: the introduction of iPhone in 2007 led to the new market of smartphones.

Other Types of Innovations

- **Product innovation**: developing new products or enhancing existing products to meet market demands and customer expectations.
- **Process innovation**: implementing new methods to improve the efficiency or reduce costs of internal processes of organizations.
- **Technological innovation:** adding new technology into products or services. This is probably the most common type of innovation.
- **Service innovation**:
  - New or improved service products
  - New or improved ways of designing and producing services

https://ideascale.com/blog/what-is-innovation/
https://en.wikipedia.org/wiki/Service_innovation

Innovations based on fluid mechanics

Drip-free Wine Bottle

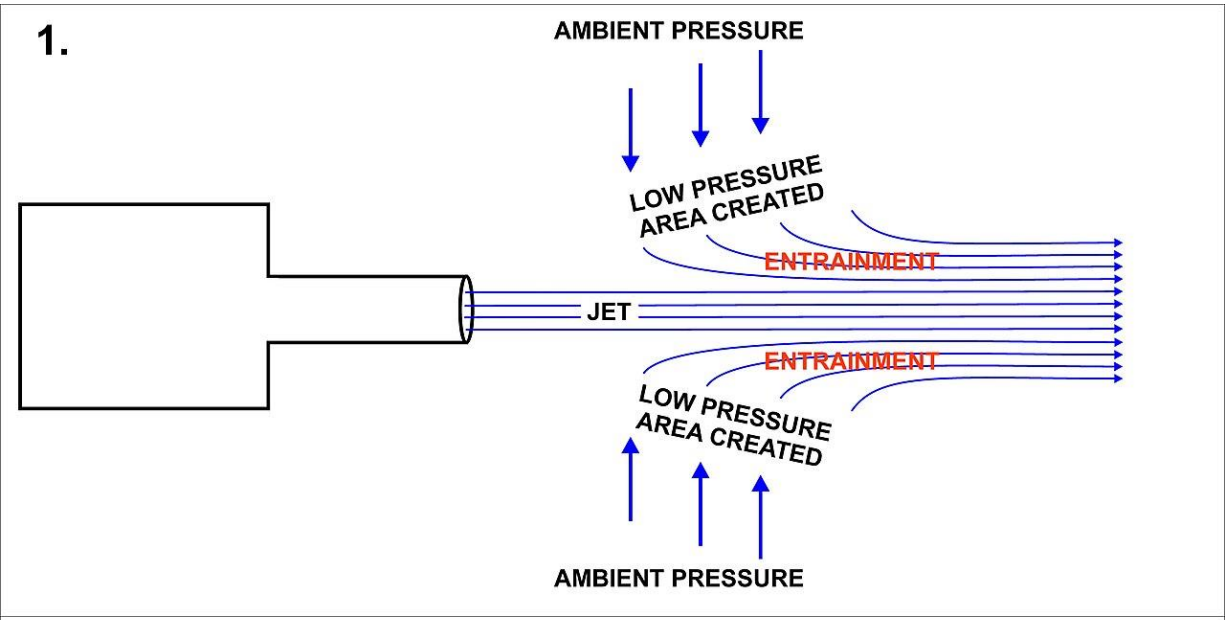
- **Pain point**: While pouring wine from a bottle, there is the drips that fall off the side of the bottle.
- **Physics involved**: the Coandă effect is the tendency of a fluid jet to stay attached to a convex surface due to an adhesive force and unbalanced force due to the surface.
- **Physics-based solution**: Introducing a groove just below the bottle lip.

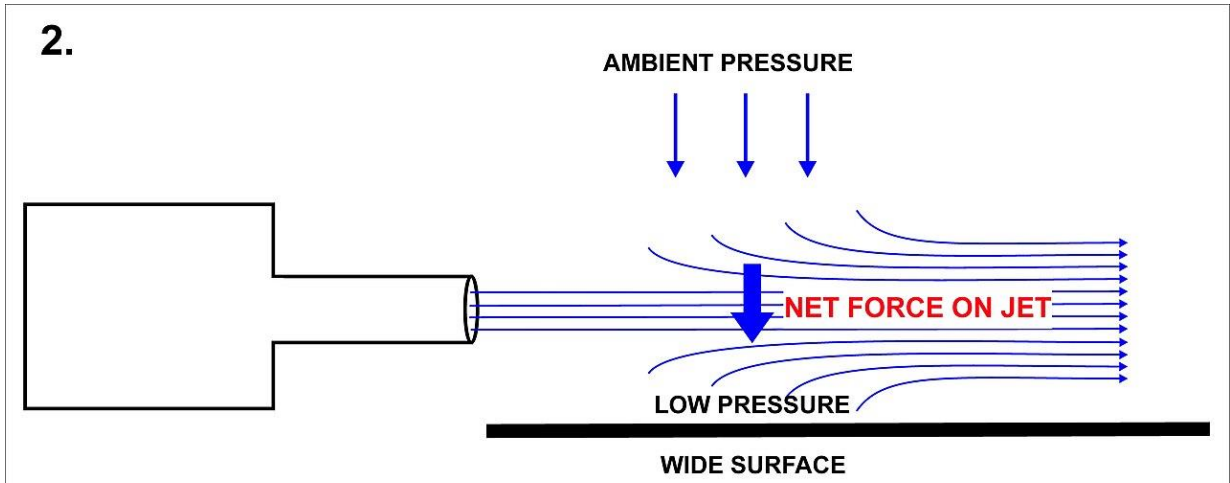
https://www.moreinspiration.com/article/6321/the-drip-free-wine-bottle?t=physics

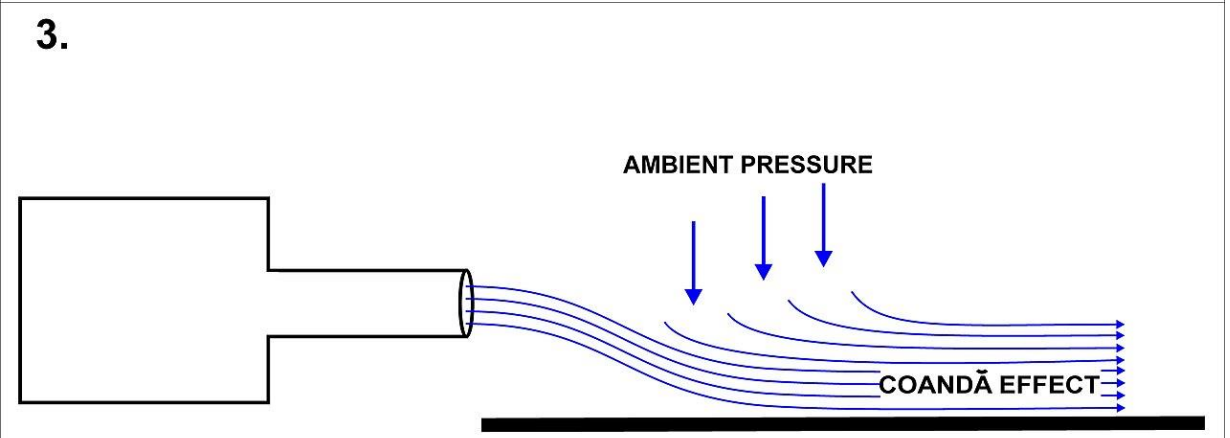
Standard
wine bottle

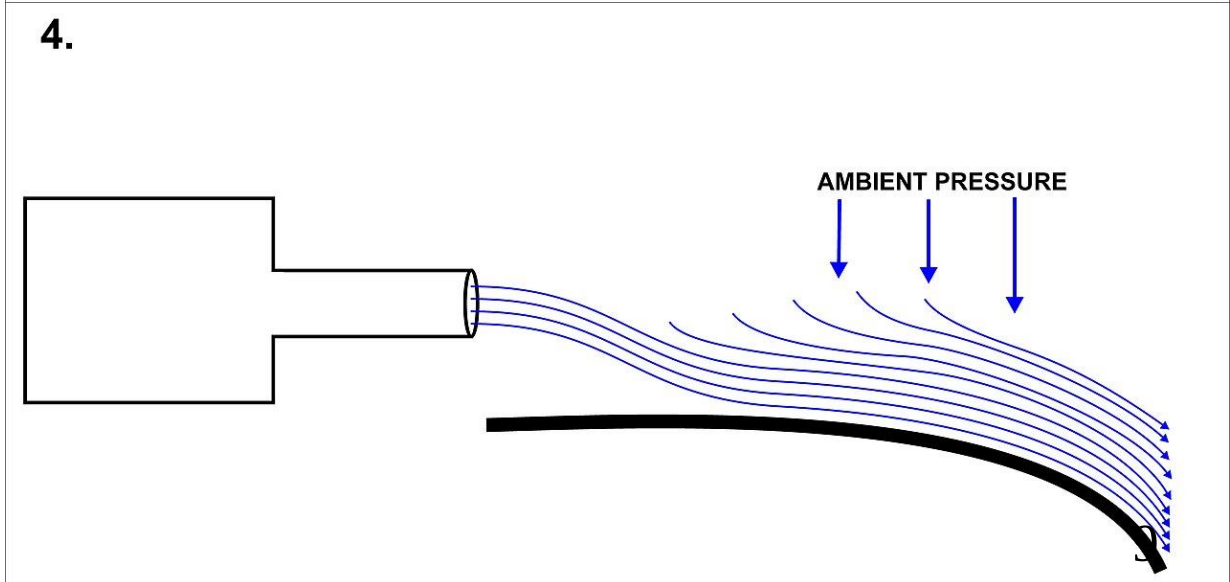
Drip-fre
wine bot

Coanda Effect Explained



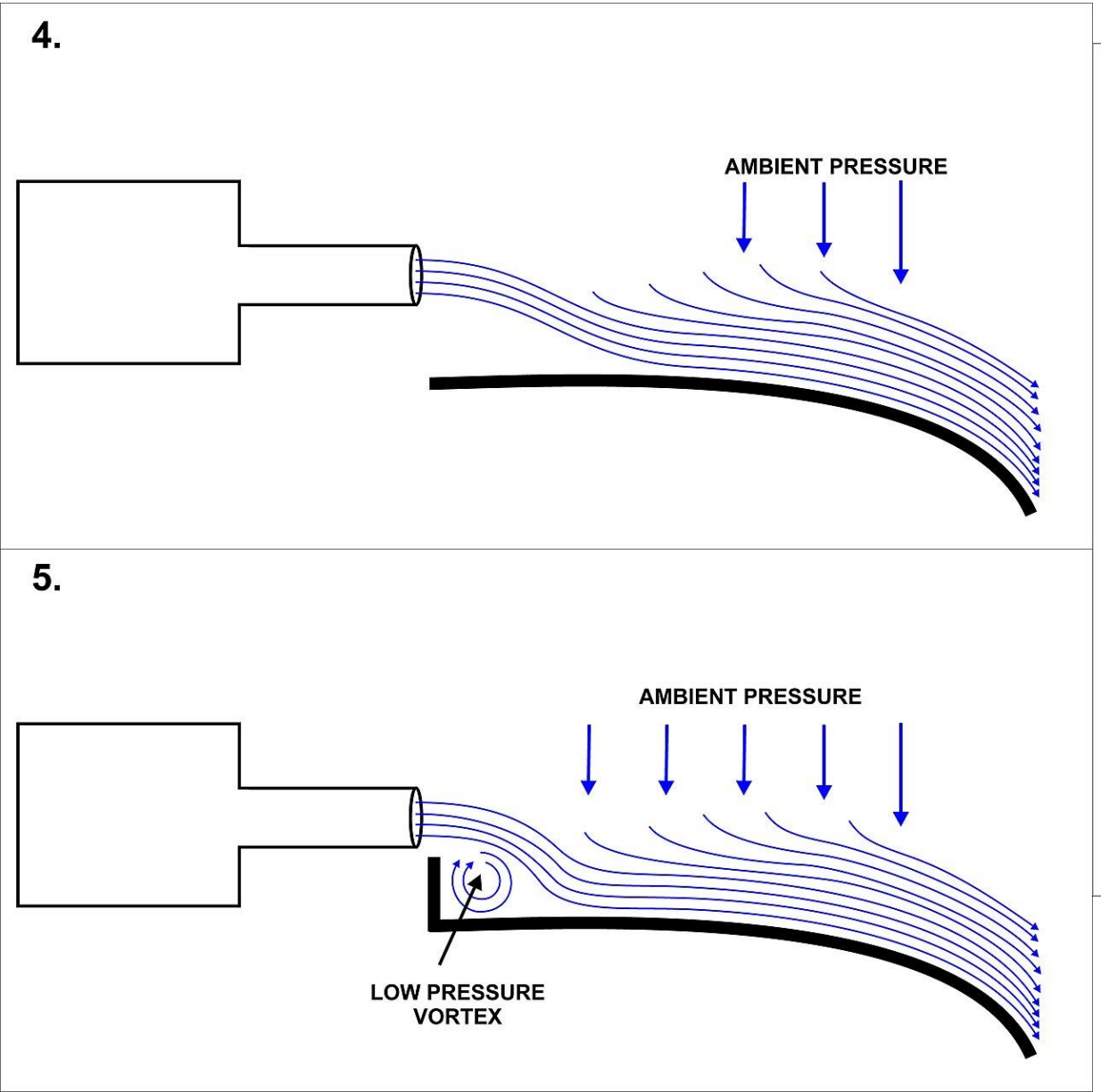


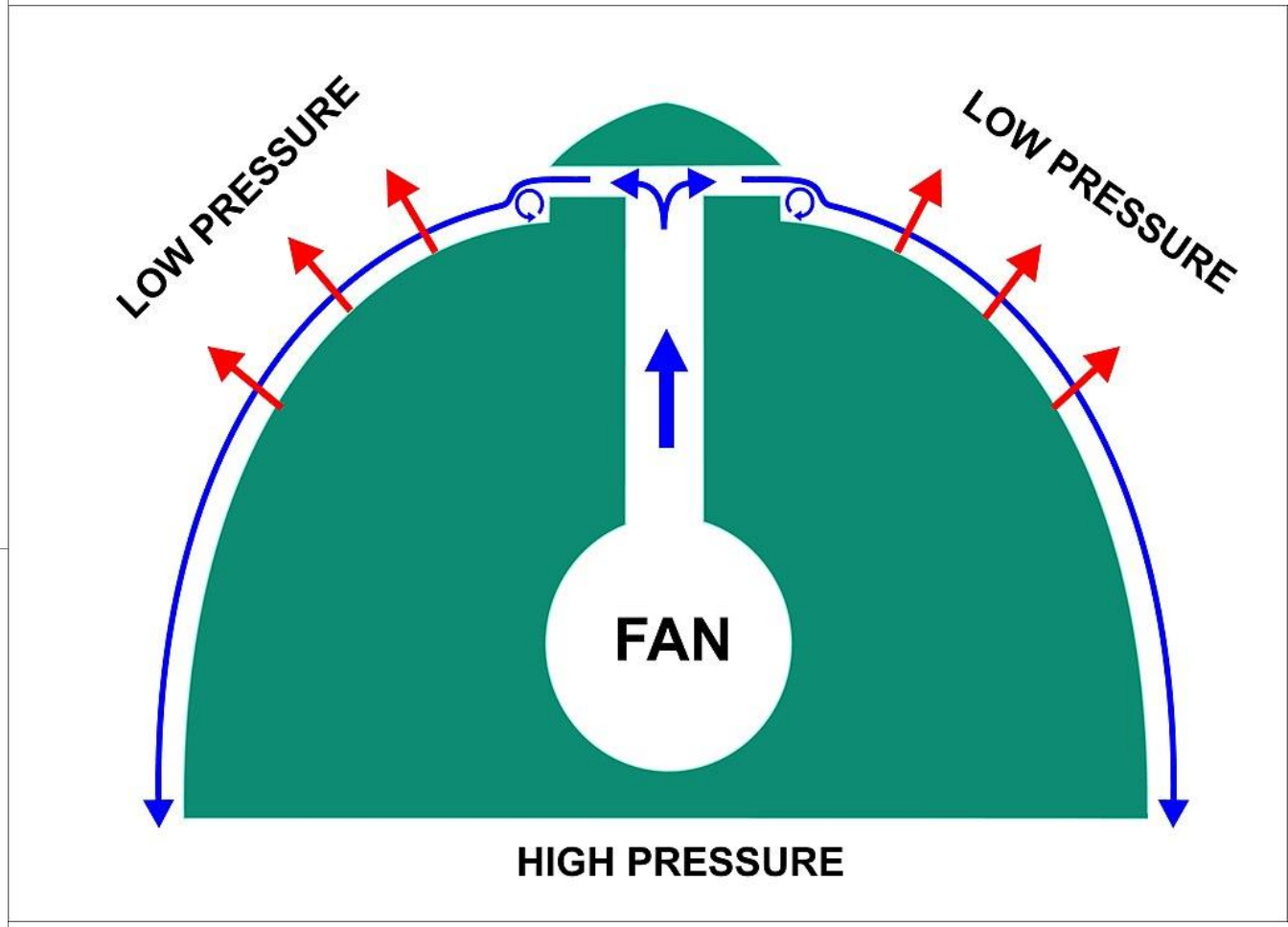




https://en.wikipedia.org/wiki/Coand%C4%83_effect

Coanda Effect Explained

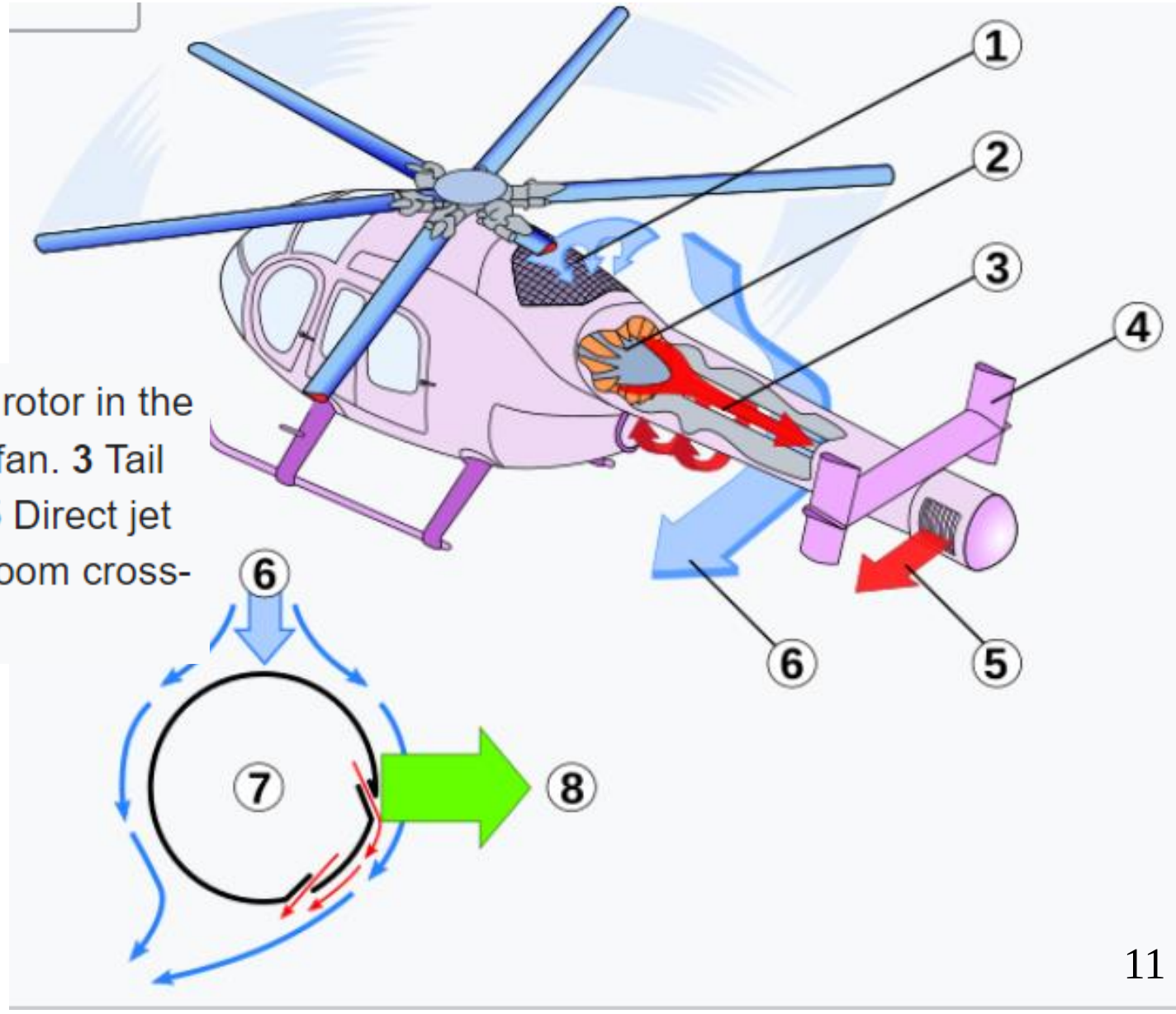




https://en.wikipedia.org/wiki/Coand%C4%83_effect

Helicopter without a Tail Rotor

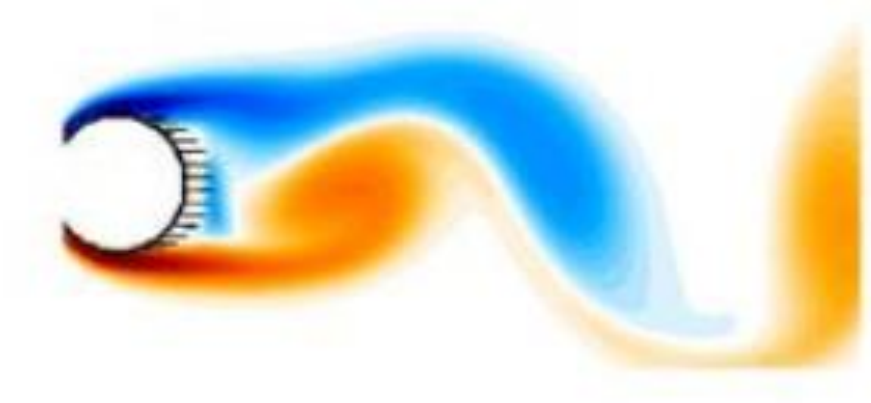
Replacing the tail rotor of a helicopter by a Coandă engine:

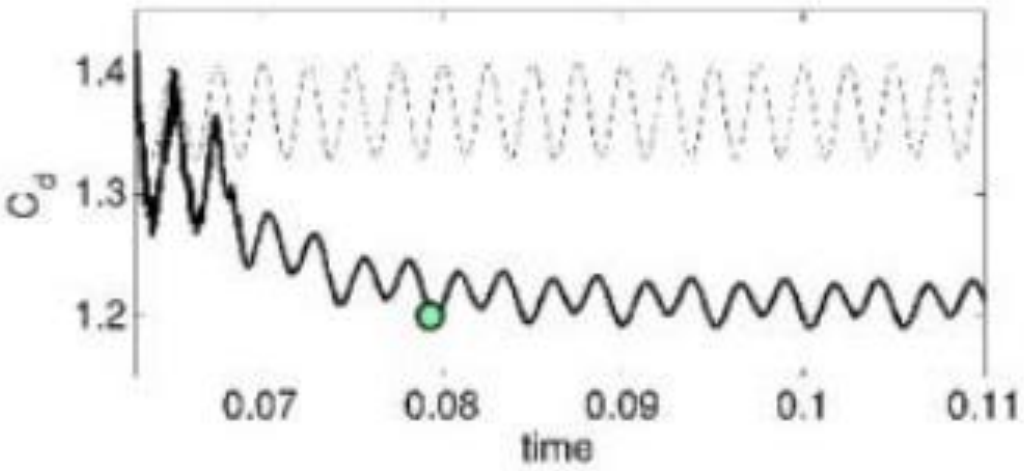


A Coandă engine (items 3,6–8) replaces the tail rotor in the NOTAR helicopter. **1** Air intake. **2** Variable pitch fan. **3** Tail boom with Coandă Slots. **4** Vertical stabilizers. **5** Direct jet thruster. **6** Downwash. **7** Circulation control tailboom cross-section. **8** Anti-torque lift.

https://en.wikipedia.org/wiki/Coand%C4%83_effect

Feather Coating to Reduce Drag

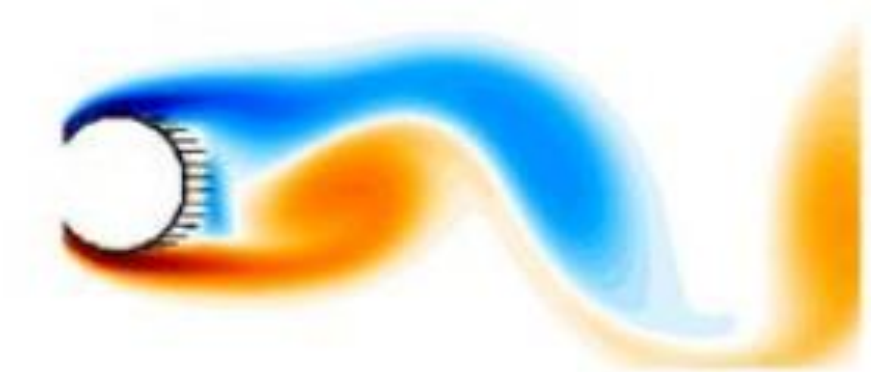


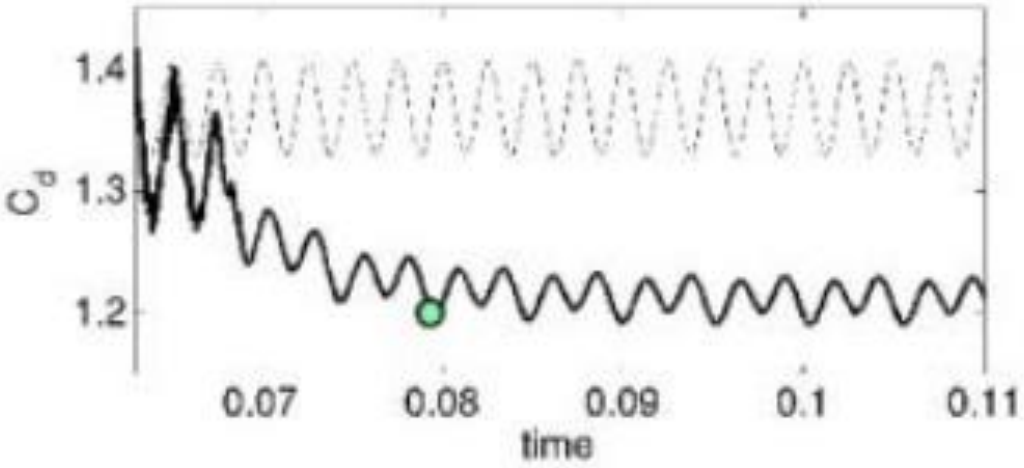


- **Pain point**: With a nonzero attack angle, an airplane wing moving through air has both lift and drag exerting on it.
- **Physics involved**: Newton's laws of motion and pressure
- **Possible solution:** Coating a cylinder with feather-like structures reduces the drag by 15%.

https://www.moreinspiration.com/article/4046/feather-coating-to-reduce-drag?t=physics

Feather Coating to Reduce Drag



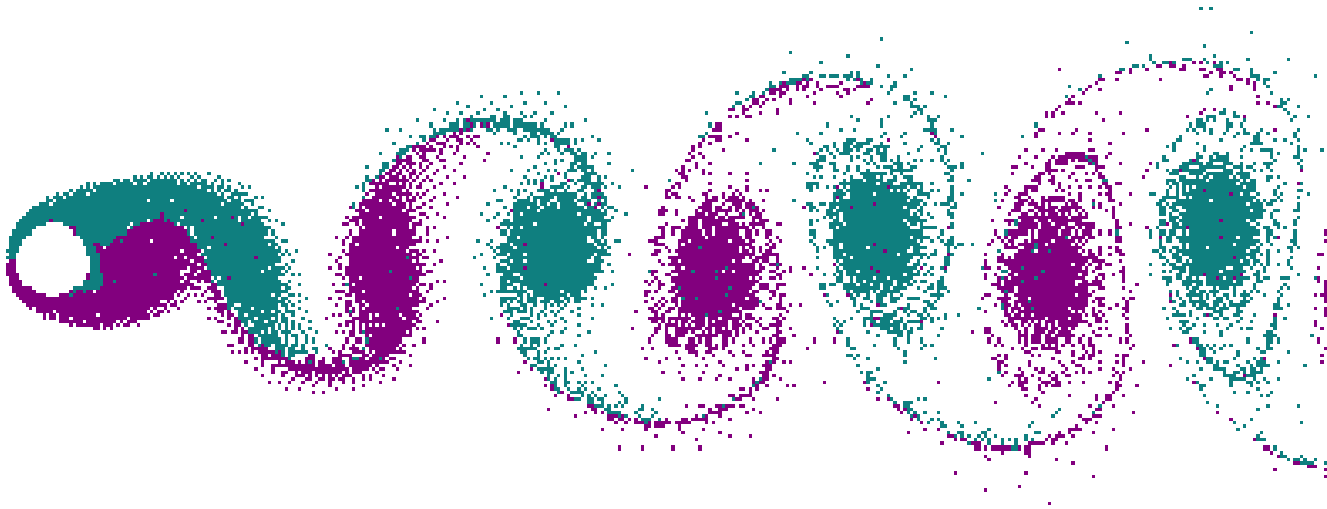


- Without the feather-like structures, “the air flows rapidly across the cylinder and creates an area of low pressure behind it.”
- “This encourages the formation of strong vortices, creating turbulence and increasing the drag on the cylinder.”

https://www.moreinspiration.com/article/4046/feather-coating-to-reduce-drag?t=physics

Karman Vortex Street

- A vortex is a region of fluid that flows around an axis.
- A Karman Vortex Street is a pattern of alternating vortices produced when a fluid flows around a bluff body under some condition.
- “These vortices create a sinusoidal force perpendicular to the flow, impacting structures like bridges and chimneys.”



https://en.wikipedia.org/wiki/K%C3%A1rm%C3%A1n_vortex_street

Karman Vortex Street

- This oscillating flow is also called vortex shedding.
- Vortex shedding occurs when the Reynolds number exceeds a certain value.
- The Reynolds number (Re) is a dimensionless quantity that measures the ratio between inertial and viscous forces.
- It can be shown that

$$\mathrm{Re} = \frac{\rho u L}{\mu}$$

where ρ is the fluid density, u is the flow speed, L is a characteristic length, and μ is the dynamic viscosity of the fluid

https://en.wikipedia.org/wiki/K%C3%A1rm%C3%A1n_vortex_street

Vortex Induced Vibration

- When a Karman vortex street occurs, alternating low-pressure vortices are created on the downstream side of the cylinder.
- This results in oscillatory forces exerting on the cylinder in the direction perpendicular to both the flow and the structure.
- The structure will vibrate due to these forces if it is not fixed.
- “Tall chimneys constructed of thin-walled steel tubes can be sufficiently flexible that, in air flow with a speed in the critical range, vortex shedding can drive the chimney into violent oscillations that can damage or destroy the chimney.”

https://en.wikipedia.org/wiki/Vortex_shedding

Strouhal Number St

- The frequency of vortex shedding in the Karman vortex street is proportional to the cylinder diameter D and the flow speed u as

$$f \propto \frac{u}{D}$$

- The Strouhal number St is the constant of proportionality, i.e.

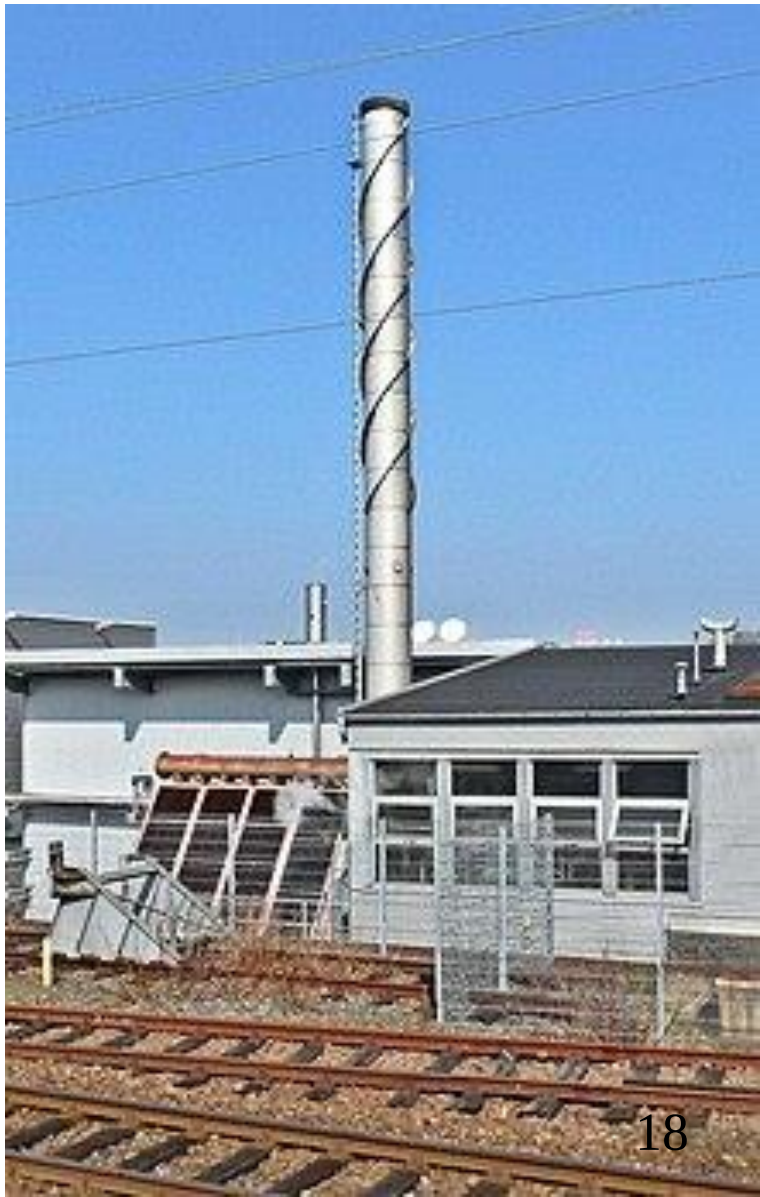
$$f = \mathrm{St}\,\frac{u}{D}$$

- “Over four orders of magnitude in Reynolds number, from 10^2 to 10^5, the Strouhal number varies only between 0.18 and 0.22.”

https://en.wikipedia.org/wiki/Vortex_shedding

Avoiding Vortex Induced Vibration

- Helical fins or strakes can be mounted on a tall tubular structure to introduce turbulence to reduce the vortex induced vibration.
- “For maximum effectiveness in suppression of vortices caused by air flow, each fin or strake should have a height of about 10 percent of the cylinder diameter. The pitch of each fin should be approximately 5 times the cylinder diameter.”



https://en.wikipedia.org/wiki/Vortex_shedding

Innovations in Wind Energy

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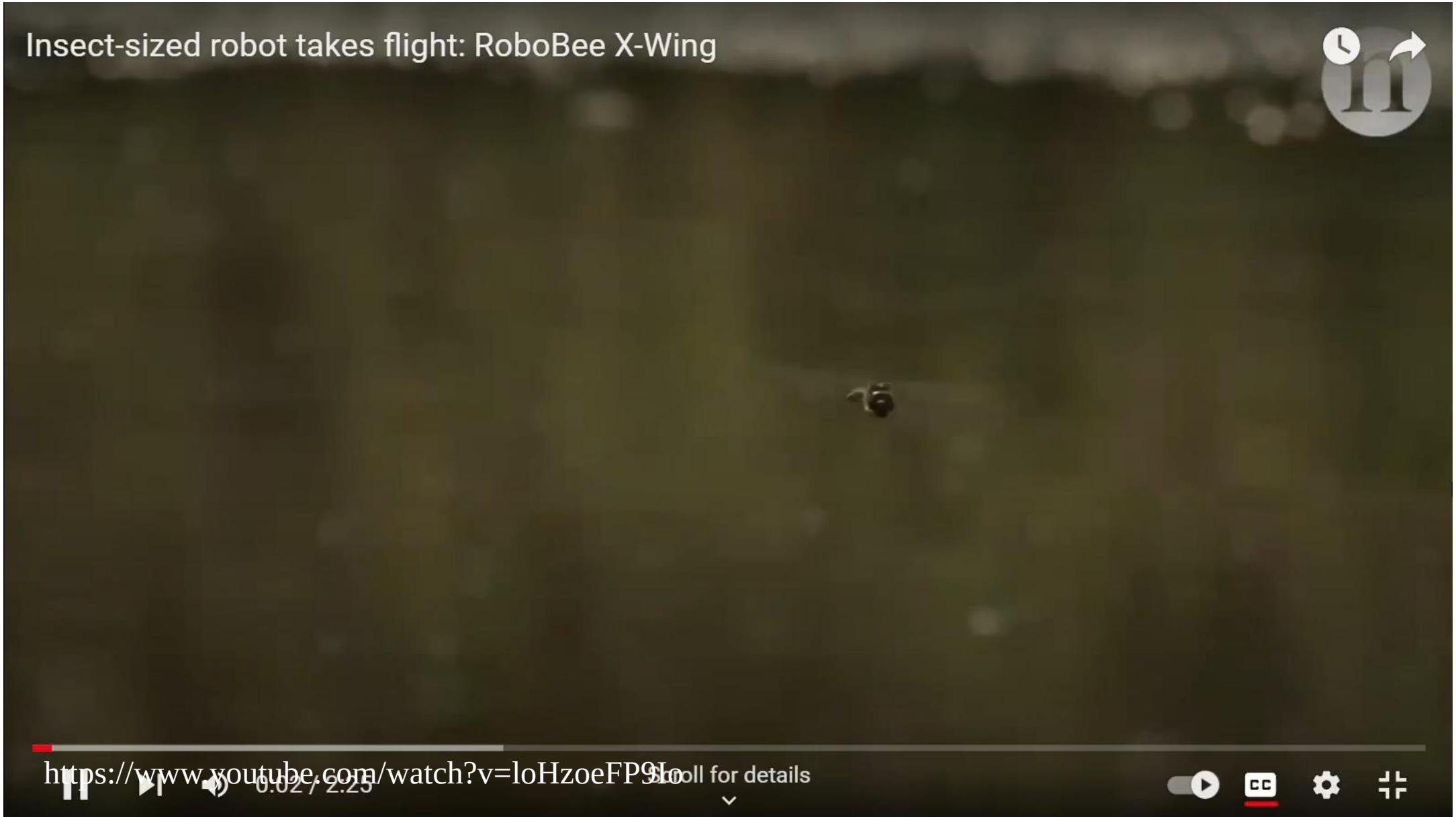
https://windcycle.energy/wind-energy-innovations/

Bird-Like Flying Robots

https://www.youtube.com/watch?v=gWq73xinEhE

Insect-Like Flying Robots



https://www.youtube.com/watch?v=loHzoeFP9Io

Jellyfish-Like Flying Robots

https://www.youtube.com/watch?v=ReDO5GR9DUA