

EFFECTS OF VARIOUS ANGLES OF ATTACK ON FLOW THROUGH BRISTLED WINGS

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Outline

- Overview of tiny insect flight at low Reynolds numbers (Re).
- Tiny insects use “clap and fling” to generate lift
- Bristled wings might reduce drag during fling.
- Experimental setup and results

Reynolds Number

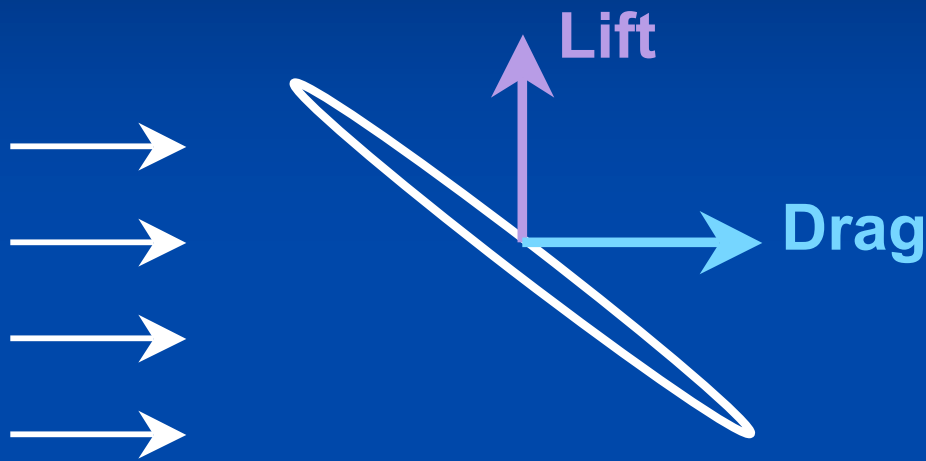
Reynolds number- a dimensionless number that describes the ratio of the inertial forces to the viscous forces in the fluid and is defined as:

$$Re = \frac{\rho l U}{\mu}$$

where

- ρ is the density of the fluid
- l is a characteristic length (chosen as the chord length of the wing or the diameter of the bristle, depending upon the problem)
- U is the free stream velocity of the fluid
- μ is the dynamic viscosity.

Lift and Drag



- Lift is defined as the vertical component of force acting against gravity.
- Drag is defined as the horizontal component of the force.

Lift and Drag Coefficients

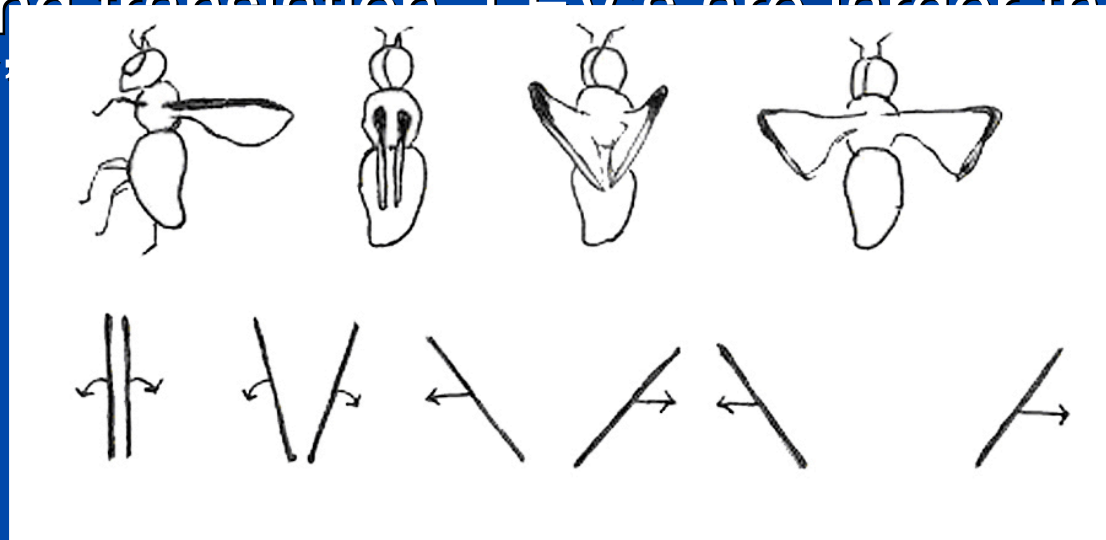
$$C_L = \frac{2 F_L}{\rho S U^2}, \quad C_D = \frac{2 F_D}{\rho S U^2}$$

Tiny insect flight

- Lift coefficients decrease and drag coefficients increase as the Re is lowered.
- Almost all tiny insects have bristled wings.
- Flight becomes less efficient at lower Re if efficiency is defined as the ratio of lift to drag forces.
- What might be some adaptations for low Re flight to improve efficiency?
 - -bristled wings
 - -clap and fling

Clap and Fling

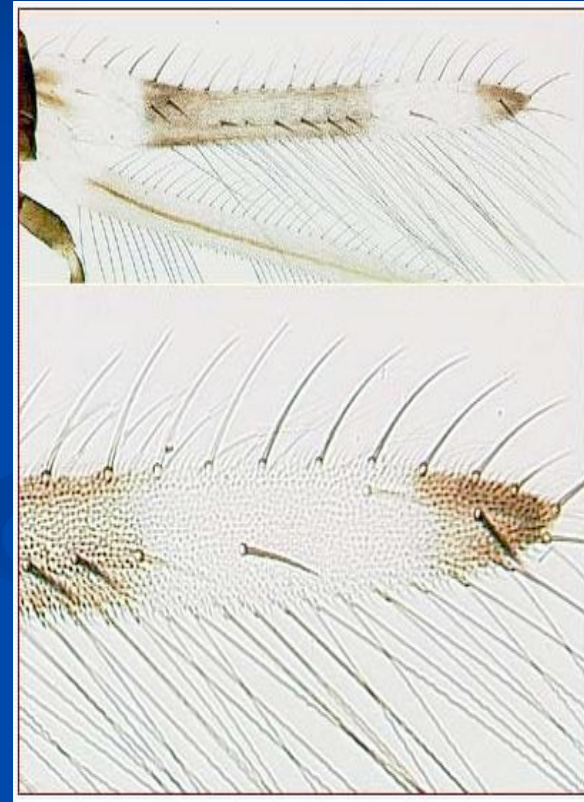
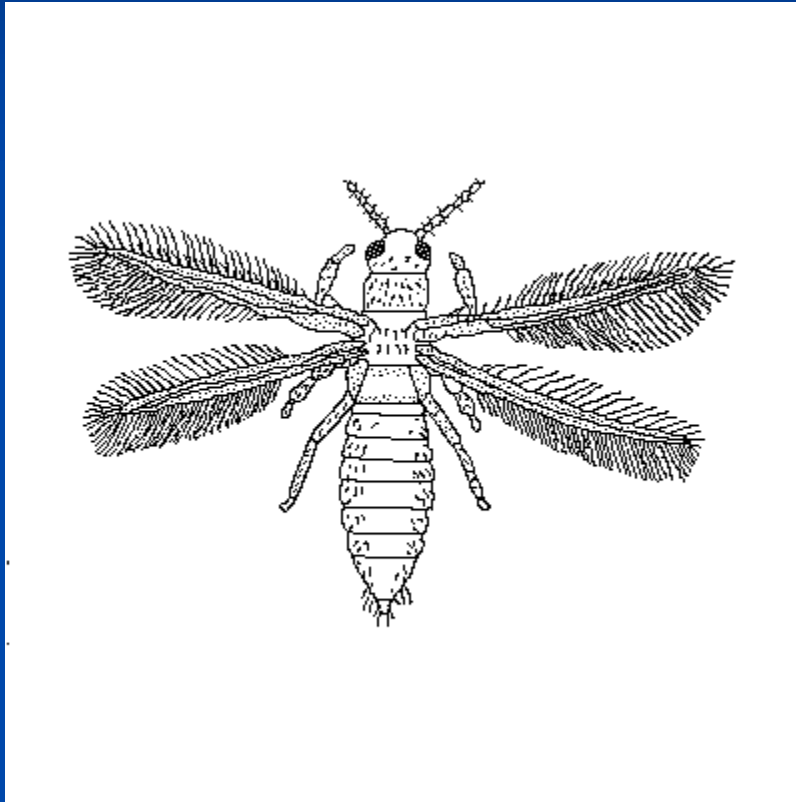
- The wings are clapped together at the end of the upstroke, and are then rotated and pulled apart.
- During wing rotation, two large leading edge vortices (LEV) form, augmenting lift.
- During translation, LEV's are larger than TEV's



The problem with fling

- Although clap and fling augments lift forces, the drag forces created during fling are more than 10 times higher than those produced during translation.
- How might drag be reduced?
 - Adding biologically realistic flexibility to the wings can half drag forces produced.
 - Wing bristles might also reduce drag.

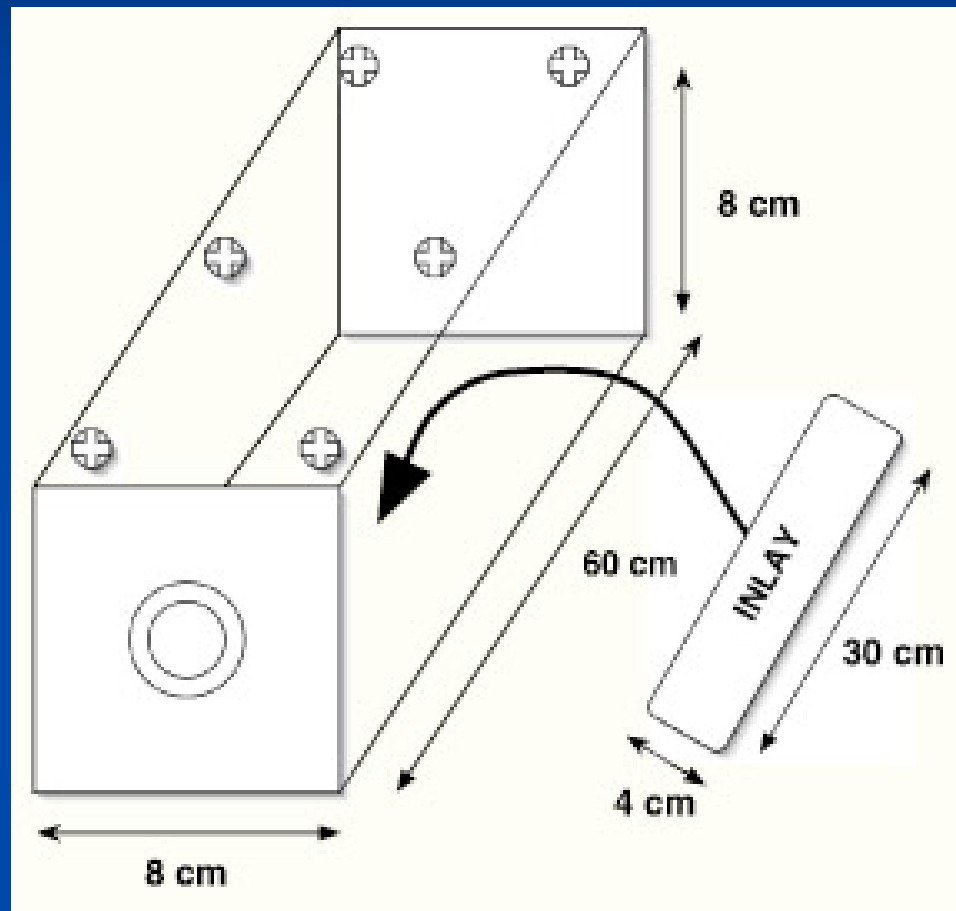
Tiny insects have bristled wings



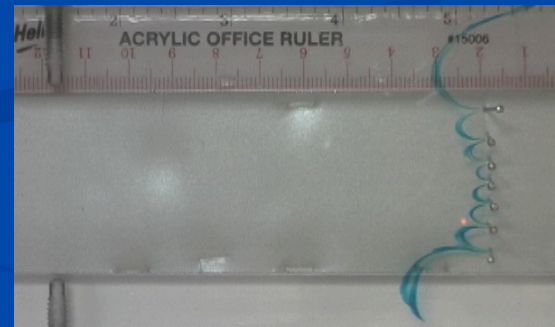
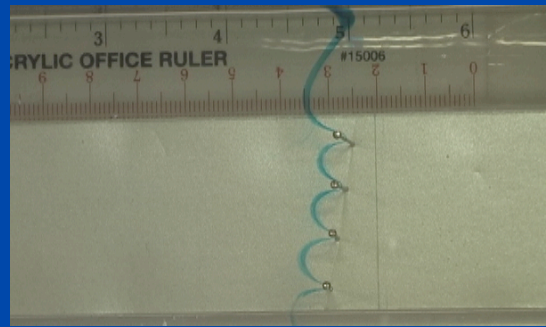
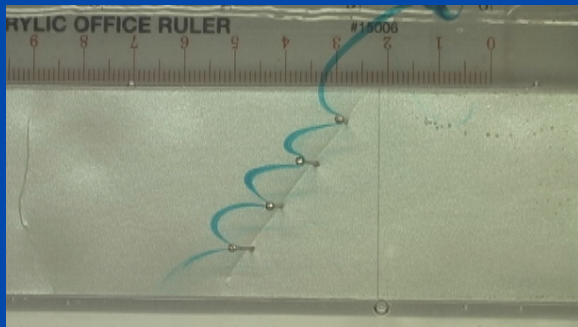
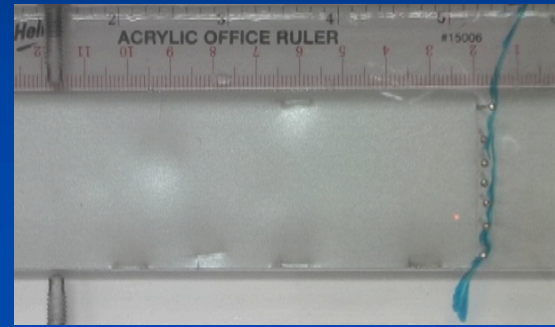
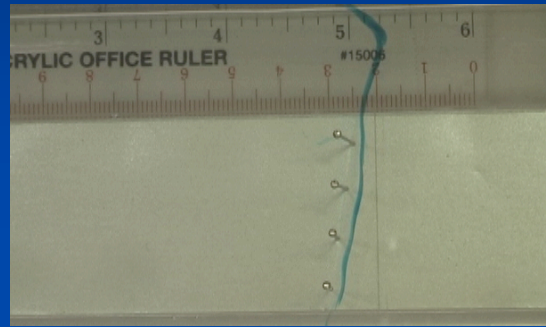
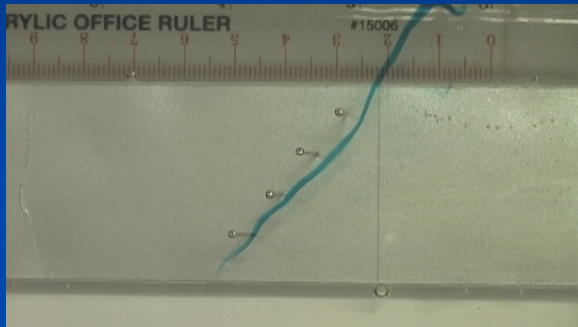
How bristles might reduce drag

- Bristled wings could act like leaky rakes during fling (when the wings are pulled apart)
- The wings might then act like lift producing solid plates during translation.
- What might cause this transition?
 - Higher characteristic Re during fling than during translation.
 - Higher angles of attack during fling.
- We need to determine how 'leakiness' depends on Re , spacing, and angle of attack.

Flow Visualization Tank



Images

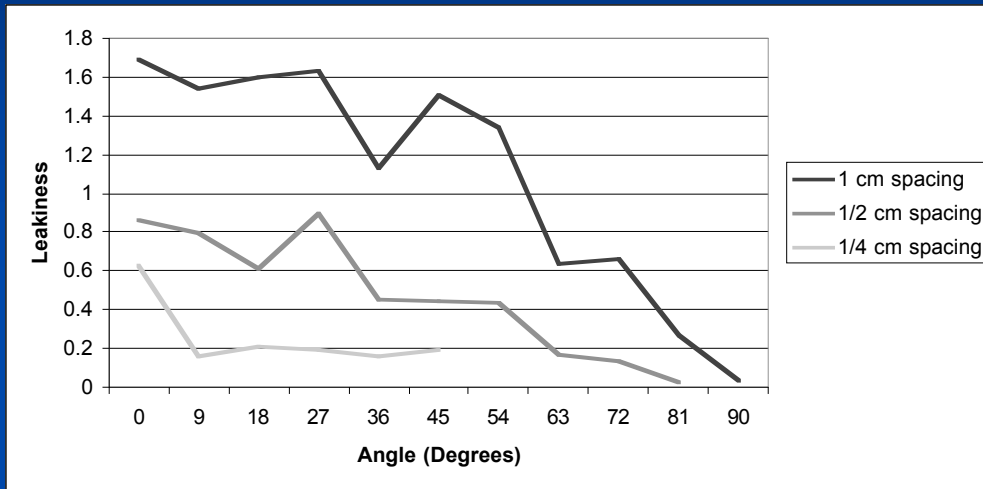


1 cm spacing for 0ω

1 cm spacing for 54ω

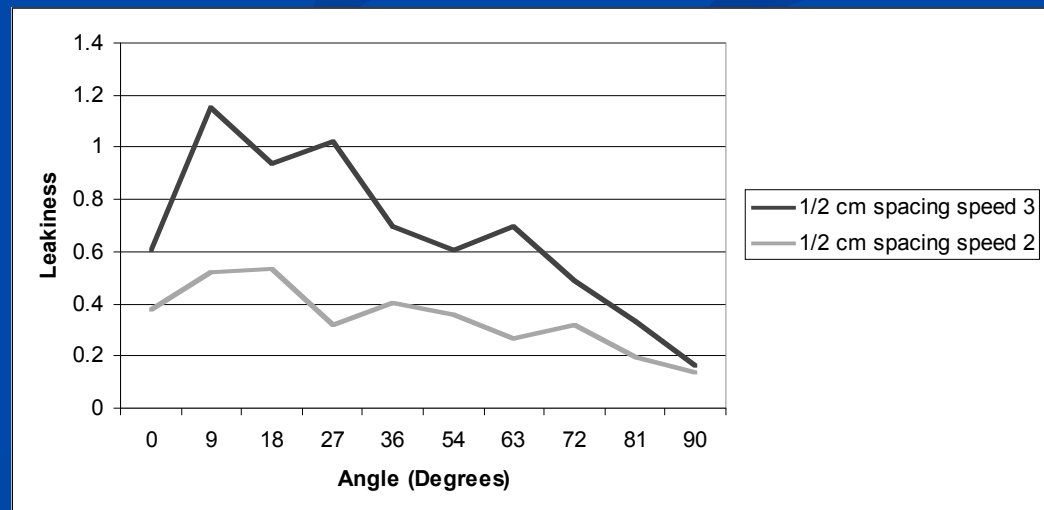
_ cm spacing for 0ω

Decreasing Re and angle of attack decreases leakiness

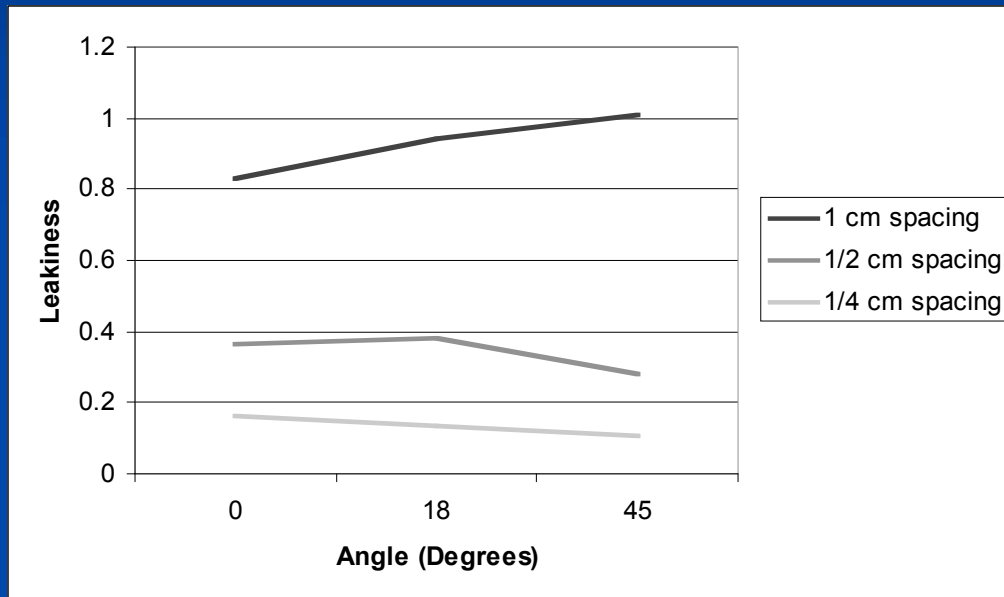


Leakiness as a function of angle in 9 degree increments from 0 to 90 degrees, for Re .047

Leakiness as a function of angle in 9 degree increments from 0 to 90 degrees for Reynolds numbers of 0.047 (speed 3) and 0.023 (speed 2) for the 1/2 cm spacing



Smaller spacing reduces leakiness



Leakiness as a function of angle for the angles of 0 degrees, 18 degrees and 45 degrees, for a Reynolds number of about 0.047

Conclusion

- Leakiness decreases with the angle of attack.
- These results might be of some help in the clap and fling motion because the greatest drag forces are generated when the wings are at a 90 degree angle of attack. This is also the place where the wings will leak the most.
- At 45 degrees, the wings act more like a solid plate. So this effect coupled with changes in leakiness due to the force acting normal to the wing could really make the wings act like leaky rakes during fling and solid plates during the rest of the stroke.

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