HIGH LIFT DEVICES

When an aircraft is landing or taking off, specially high values of lift coefficient are required in order to maintain flight at the desired low speeds.

$$L = \frac{1}{2}\rho_\infty V_\infty^2 S C_L$$

- Increasing the area S.
- Increasing the lift coefficient C_L by using much more camber.
- Delay the flow separation by controlling the behavior of the boundary layer.

High Lift Device (I)

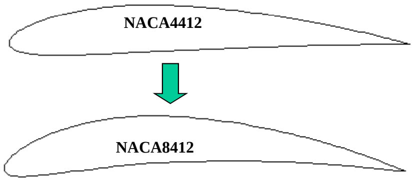
(I) Biplane (SPAD XIII in WWI)

- No good structure analysis limit the surface area one could obtained with a single wing.
- Extra weight of the wings

The increase of lift

- Drag increase , too.

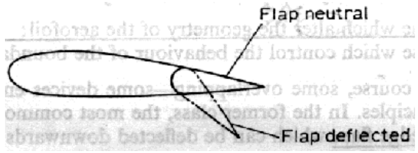
(II) More Cambered Airfoil

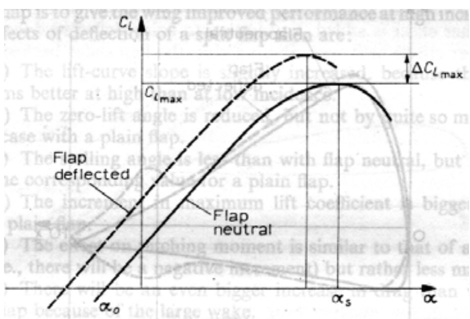


- Lift increase, but drag increase, too.
- Stall angle of attack decrease.

High Lift Device (II)

(III) Plain Flap





- Give increase in maximum lift when required at taking off or landing.
- The lift increase with flap deflection increase.
- Stall angle decrease.

High Lift Device (III)

(IV) Split Flap

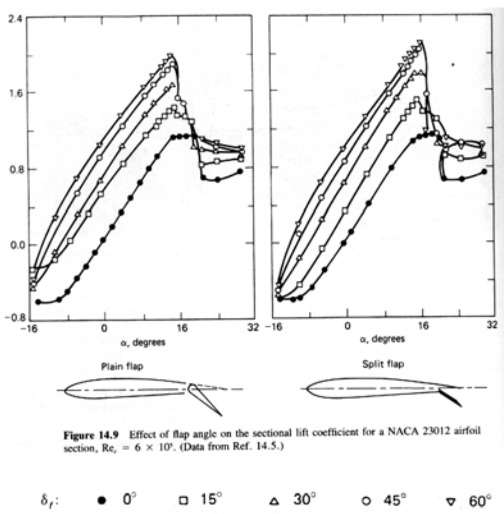
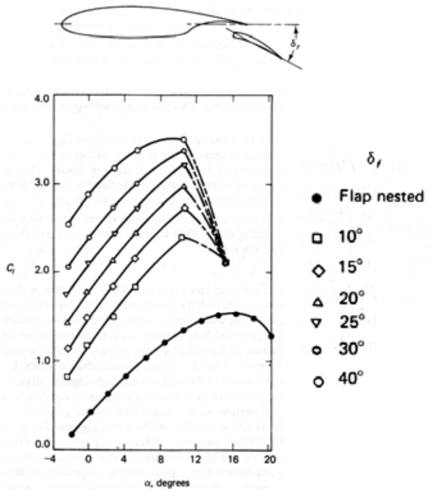


Figure 14.9 Effect of flap angle on the sectional lift coefficient for a NACA 23012 airfoil section, $Re_c = 6 \times 10^6$. (Data from Ref. 14.5.)

- The stalling angle is higher than the corresponding value for a plain flap.
- The increase in lift coefficient is bigger than with a plain flap.
- There will be bigger increase in drag than with a plain flap because of the large wake.

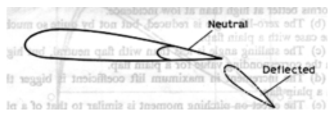
High Lift Device (IV)

(V) Slot Flap



- Air blow through the slot, re-energizes the boundary layer, and tend to prevent separation.

(VI) Fowler Flap

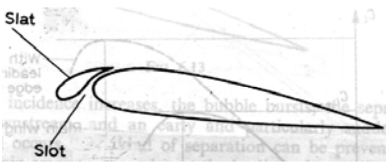


- Additional provides an increase in the effective wing area.

AERODYNAMICS (W5-3-5)

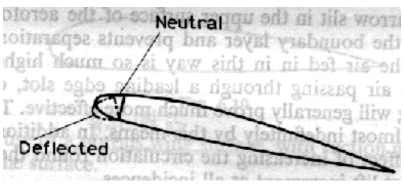
High Lift Device (V)

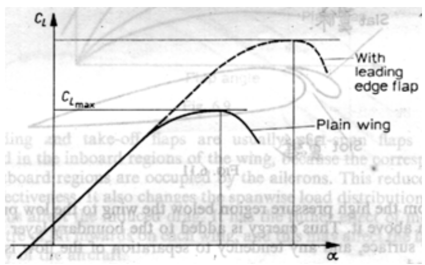
(VII) Leading Edge Slat



Fi 156 (fixed leading edge slat)

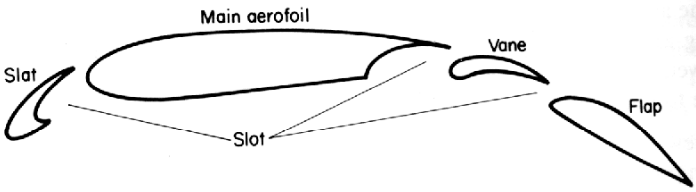
(VIII) Leading Edge Flap



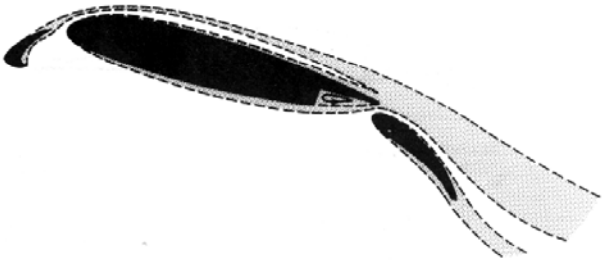


AERODYNAMICS (W5-3-6)

Multi-element Airfoil

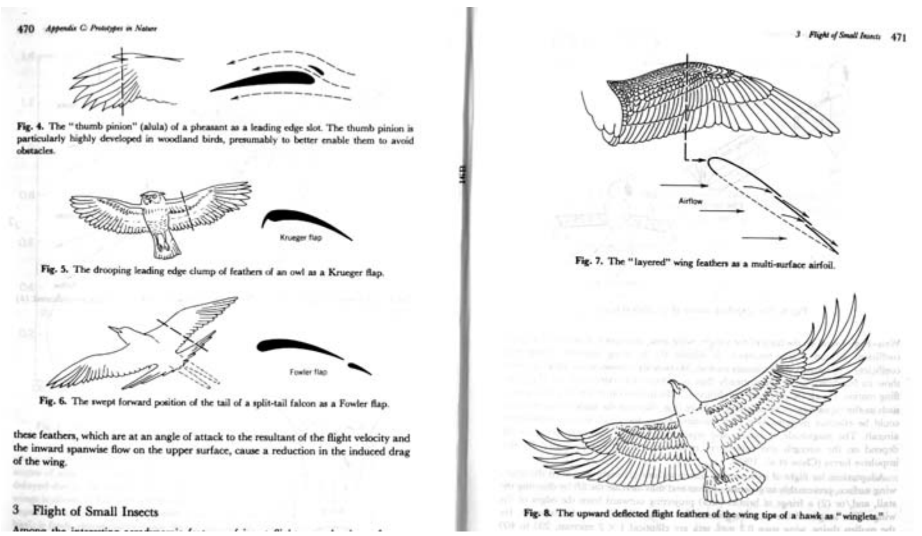


Boundary layer behavior for a multi-element airfoil



AERODYNAMICS (W5-3-7)

SUMMARY



470 *Appendix C Prototypes in Nature*

Fig. 4. The "thumb pinion" (alula) of a pheasant as a leading edge slot. The thumb pinion is particularly highly developed in woodland birds, presumably to better enable them to avoid obstacles.

Krueger flap

Fig. 5. The drooping leading edge clump of feathers of an owl as a Krueger flap.

Fowler flap

Fig. 6. The swept forward position of the tail of a split-tail falcon as a Fowler flap.

these feathers, which are at an angle of attack to the resultant of the flight velocity and the inward spanwise flow on the upper surface, cause a reduction in the induced drag of the wing.

3 Flight of Small Insects

3 Flight of Small Insects 471

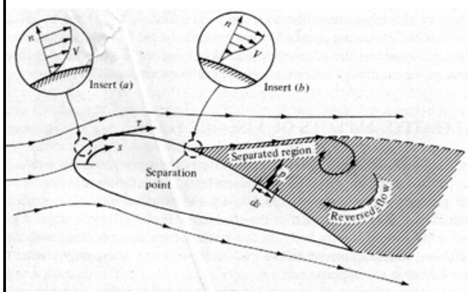
Airflow

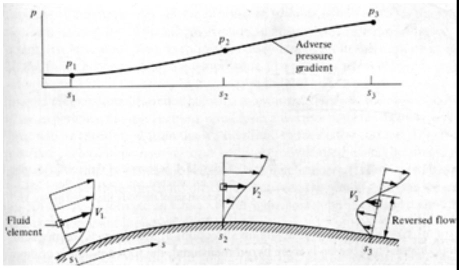
Fig. 7. The "layered" wing feathers as a multi-surface airfoil.

Fig. 8. The upward deflected flight feathers of the wing tips of a hawk as "winglets."

AERODYNAMICS (W5-3-8)

SEPARATION CONTROL



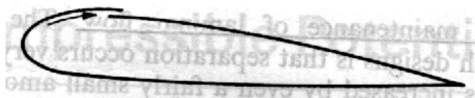


- Prevent or delay the flow separation by controlling the behavior of the boundary layer

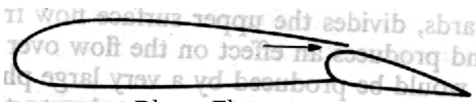
=> increase the stall angle and maximum lift

Boundary Layer Control (I)

- Re-energizes the fluid inside the boundary layer by blowing:

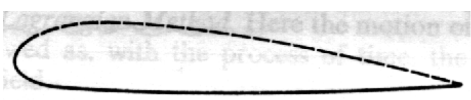


blowing on upper surface of airfoil



Blown Flap

- Remove the low energy fluid inside the boundary layer by suction:

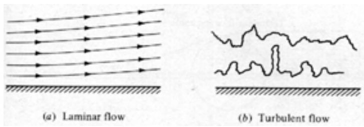


Suction applied on the upper porous wing surface

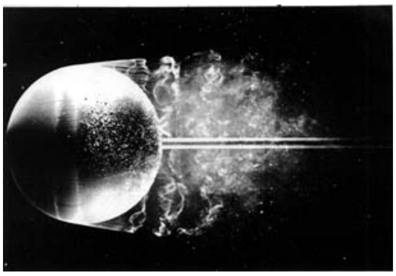
Boundary Layer Control (II)

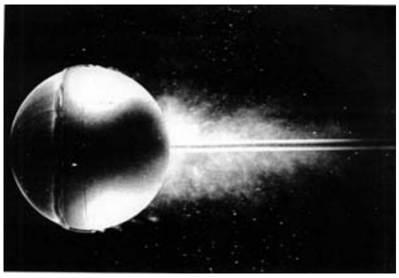
- Increase momentum exchange between the fluid inside and outside the boundary layer to prevent or delay the seaparation:

(i) Trip the boundary layer become turbulent on the surface of airfoil



$$\left[\left(\frac{\partial V}{\partial n}\right)_{n=0}\right]_{\text{turbulent}} > \left[\left(\frac{\partial V}{\partial n}\right)_{n=0}\right]_{\text{laminar}}$$

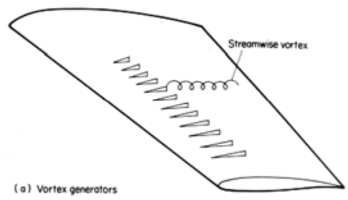




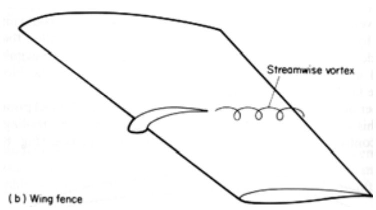
AERODYNAMICS (W6-1-3)

Boundary Layer Control (III)

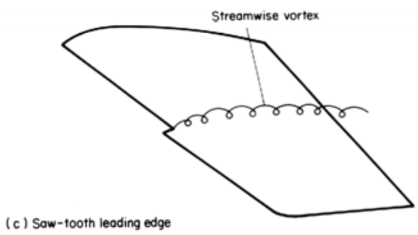
(ii) Vortex generator



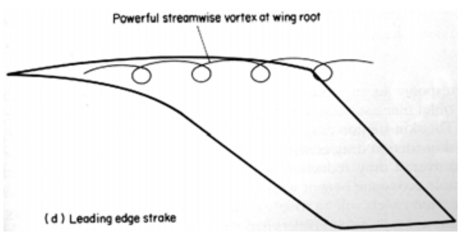
(iii) Wing fence



(iv) Saw-tooth edge



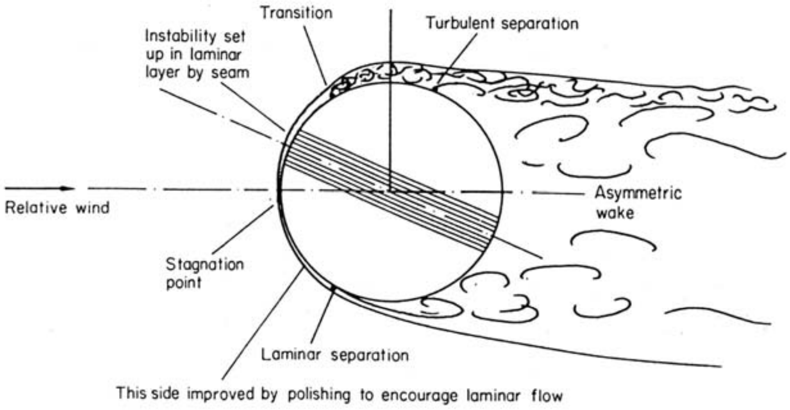
(v) Leading edge strake



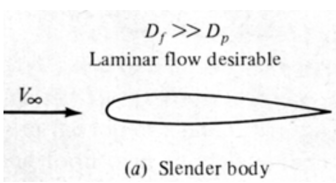
AERODYNAMICS (W6-1-4)

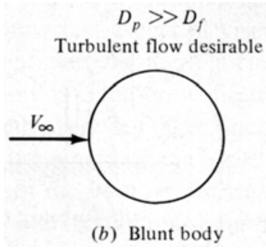
Leading edge strake vortex system of F16 Fighter

Criket Ball



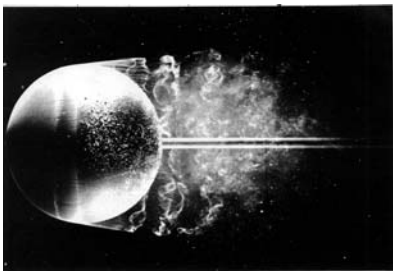
DRAG REDUCTION





$\boxed{\textbf{Total drag } D = D_P + D_f + D_i}$

30 to 40% of total aircraft drag



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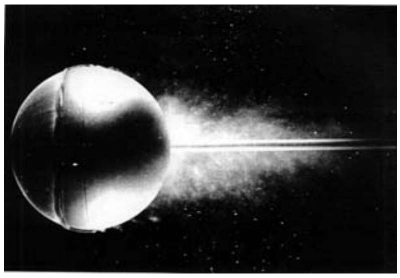
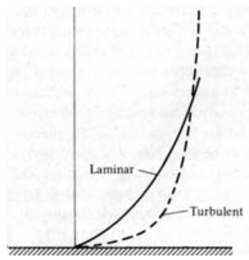


SKIN FRICTION DRAG REDUCTION (I)

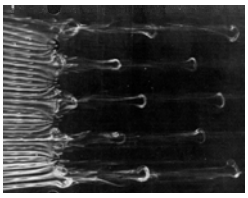
(i) Laminar flow technology to postpone the transition from laminar to turbulent boundary layer flow.

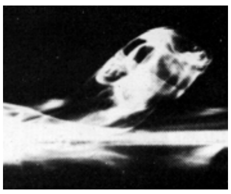
- laminar airfoil to prolong the favorable or constant pressure region over the wing surface.
- Apply suction to remove turbulent fluid inside the boundary layer.

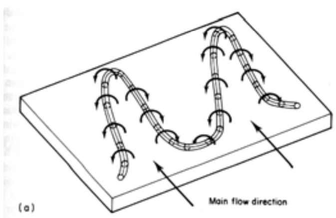


(Skin friction)$_{\text{laminar}}$ < (Skin friction)$_{\text{turbulence}}$

(ii) Turbulent boundary layer control



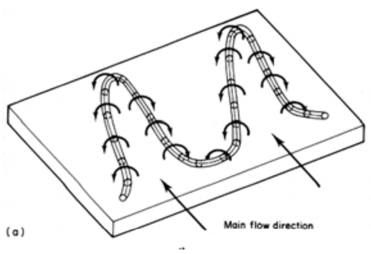


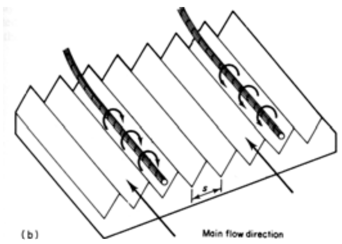


Horse-shoe vortex structures inside the turbulent boundary layer

SKIN FRICTION DRAG REDUCTION (II)

Method I: Passive control - two dimensionalize the turbulent boundary layer structure can reduce the skin-friction drag



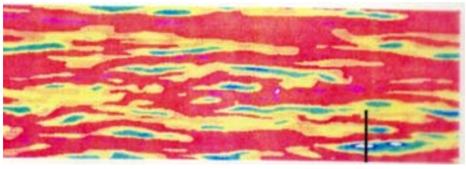


Use riblet tape to two-dimensioanlize the near-wall turbulence structures.

=> 3%-8% drag reduction

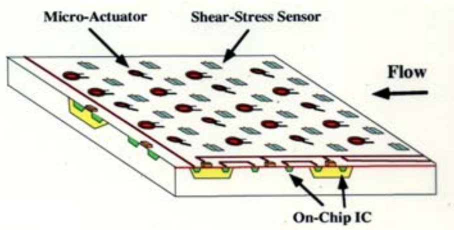
SKIN FRICTION DRAG REDUCTION (III)

Method II: Active control - to detect the high shear stress region and remove the high shear stress region by blowing from surface or micro vortex generators.



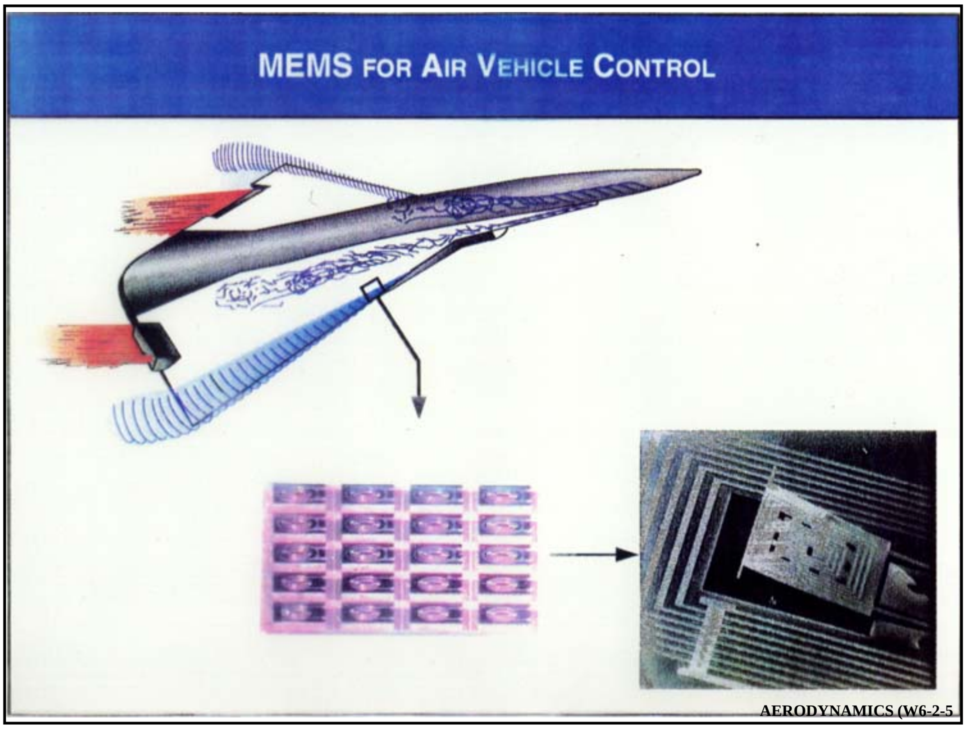
Footprints of the drag producing vocitices

- **random small vortices (500 μm)**
- **short life time (msec)**



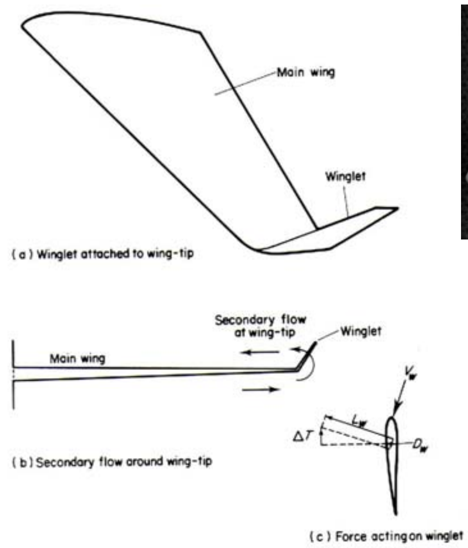
Real time control of random events by

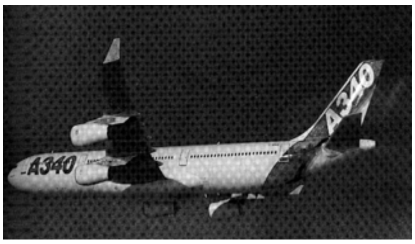
distributed sensors + local control decision + actuators



AERODYNAMICS (W6-2-5

INDUCED DRAG REDUCTION





AERODYNAMICS (W6-2-6)