2.25

8 Boundary Layers, Separation, and the Effect on Drag and Lift

8.1 The nature of solutions of the Navier-Stokes equations at high Reynolds numbers: separation of the flow into an inviscid outer flow with slip at "the wall" and a thin viscous boundary layer very near the wall; the method of matched asymptotic solution.

8.2 The boundary layer equations and their boundary conditions; the coupling between the inviscid outer flow and the boundary layer flow.

8.3 Blasius's similarity solution for the flow over a semi-infinite flat plate: the laminar flat-plate boundary layer (uniform outer flow with zero pressure gradient).

8.4 Comparison with experiment. Transition to turbulence in the boundary layer. Empirical stress and drag correlations for the fully turbulent flat-plate boundary layer. Effect of surface roughness on shear drag.

8.5 The nature of boundary layers in flows with pressure varying over the wall. Flow separation and its consequences. Fact: a boundary layer is less prone to separation when it is turbulent.

Secondary flows caused by boundary layers: e.g. "the tea leaves problem" & secondary flow in bends.

8.6 Separation and drag. On blunt bodies, drag is mainly pressure drag, and decreases when the boundary layer turns turbulent. On very slender bodies, the drag is mainly viscous drag, and increases when the boundary layer turns turbulent.

8.7 Separation and lift. Why the lift-to-drag ratio increases when the boundary layer over an airfoil becomes turbulent, and why higher lift can be achieved with turbulent flow in the boundary layer.

8.8 Comments on boundary layer control (delay of separation).

8.9 Integral method for solving the (laminar) boundary layer equation. Examples.

Reading: Fay, pp. 311-324;
See also other texts.
Handouts of data on drag and on lift.

Problems: Shapiro & Sonin, 9.4, 9.5, 9.6, 9.11.