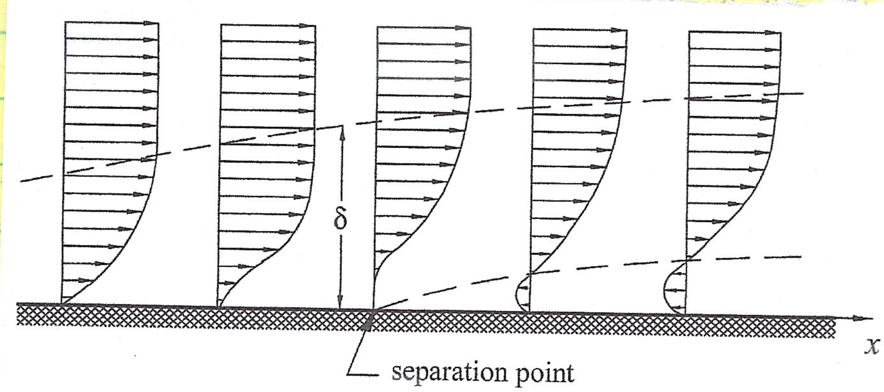

FIGURE 9.8 Velocity profiles in a boundary layer in the vicinity of separation.

note BL theory $p_y = 0$ across δ

Low momentum fluid near wall responds first to adverse pressure gradient resulting in reverse flow, ie, BL separates from surface and is deflected over reverse flow region.

Prior separation $u_y > 0$ ie $\tau_w = \mu u_y > 0$ and opposes outer flow

After separation $u_y < 0$ ie $\tau_w < 0$

Definition 2D separation: $u_y = 0$ ie $\tau_w = \mu u_y = 0$

∴ Separation can only exist in region $p_x > 0$

$\mu u_{yy} = p_x$ ie curvature $u \propto p_x$ at $y = 0$

Note for $p_x = 0$ ie flat plate BL, PI at $y = 0$

$p_x < 0$ $u_{yy} < 0$ at $y = 0$ and remains < 0 same as at δ
ie no separation will occur and no PI

$p_x > 0$ $u_{yy} > 0$ at $y = 0$ and since < 0 at δ
must have PI $0 < y < \delta$ and separation
may occur for sufficiently large p_x

Or can explain in terms of u_y but all BL have PI when $p_x > 0$

$p_x > 0 \Rightarrow \frac{\partial}{\partial y}(\mu u_y)\Big|_{y=0} > 0$ ie $u_y > 0$ at $y = 0$ & therefore since $\tau = \mu u_y = 0$ for $y \geq \delta$ must have maximum within δ, which implies PI since $\mu u_y = 0\Big|_{\tau_{max}}$ ie $\mu u_{yy} = 0$

Since $U(x) \neq f(Re)$, prediction separation seemingly at least for laminar flow without viscous/inviscid interaction does not depend on Re. Interestingly even for bluff bodies with transition from laminar to turbulent flow (circular cylinder & sphere) with large wake (viscous/inviscid interaction) x_{sep} not very sensitive Re

Separation types:

① bluff body ie large wake, which changes effective body shape due δ^*

② slender body ie only local perturbation $U(x)$ eg airfoil LE separation bubble & TE separation

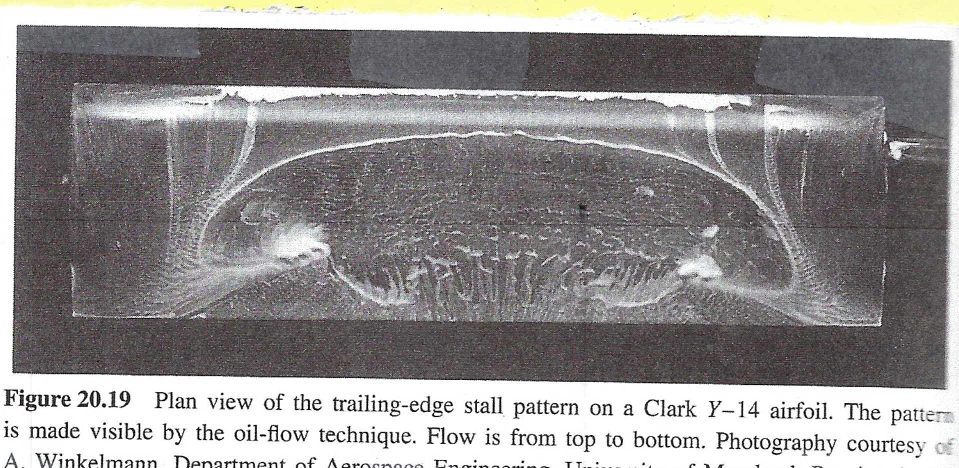

Figure 20.19 Plan view of the trailing-edge stall pattern on a Clark Y–14 airfoil. The pattern is made visible by the oil-flow technique. Flow is from top to bottom. Photography courtesy of A. Winkelmann, Department of Aerospace Engineering, University of Maryland. Reprinted with permission.

Separation is usually 3D