(a) (i) $F(z) = U\left(z + \frac{a^2}{z}\right)$

- $F(z)$ is analytic.
- $F(z) \rightarrow Uz$ for $|z| \rightarrow \infty$. Uz is the complex potential for uniform flow with x component velocity U.
- On the cylindrical surface, $z = ae^{i\theta}$, we have

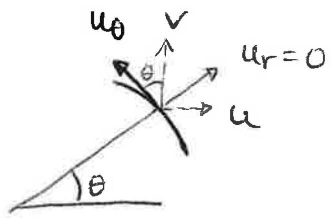
$$F(z) = Ua\left(e^{ia} + e^{-i\theta}\right) = 2U\cos\theta$$

$$\psi = \mathrm{Im}[F(z)] = 0 \Rightarrow \text{the cylinder is a streamline}$$

(ii) On the surface, at angle θ:

$u = -u_\theta \sin\theta$

$v = u_\theta \cos\theta$



$$u - iv = -u_\theta(\sin\theta + i\cos\theta) = -ie^{-i\theta}u_\theta$$

i.e, $u_\theta = ie^{i\theta}(u - iv)$.

$$u - iv = F'(z) = U\left(1 - \frac{a^2}{z^2}\right) = U\left(1 - e^{-2\theta i}\right) \quad \text{for } z = ae^{i\theta}$$

$$u_\theta = ie^{i\theta}(u - iv) = -2U\sin\theta$$

(iii) The reduction in velocity at the rear half of the Cylinder (from $2U$ at $\theta = \pi/2$ to zero at $\theta = 0$), which would be associated with severe adverse pressure gradients.

$\boxed{1-2}$

(b) (i) The additional contribution to the complex is

$$F_s(z) = \frac{m}{2\pi}\left[\log z - \log(z - a^2/b) - \log(z-b)\right]$$

$$= \frac{m}{2\pi}\log\left[\frac{z}{(z-a^2/b)(z-b)}\right]$$

On cylinder, $z = ae^{i\theta}$:

$$F_s(z) = \frac{m}{2\pi}\log\left[\frac{1}{(1-\frac{a}{b}e^{-i\theta})(ae^{i\theta}-b)}\right]$$

$$= \frac{m}{2\pi}\log\left(\frac{-b}{|ae^{i\theta}-b|^2}\right)$$

Hence $\mathrm{Im}[F_s(z)] = \text{constant}$,

and the cylinder surface is still a streamline.

(ii) $$(u-iv)_s = F_s'(z) = \frac{m}{2\pi}\left[\frac{1}{z} - \frac{1}{z-a^2/b} - \frac{1}{z-b}\right]$$

On $z = ae^{i\theta}$ $$(u-iv)_s = \frac{m}{2\pi ae^{i\theta}}\left[1 - \frac{b}{b-ae^{-i\theta}} + \frac{ae^{i\theta}}{b-ae^{i\theta}}\right]$$

$$= \frac{m}{2\pi ae^{i\theta}}\left[-\frac{ae^{-i\theta}}{b-ae^{-i\theta}} + \frac{ae^{i\theta}}{b-ae^{i\theta}}\right]$$

$$= \frac{m}{2\pi e^{i\theta}}\left[\frac{b\cdot 2i\sin\theta}{b^2+a^2-2ab\cos\theta}\right]$$

$$= \frac{imb}{\pi e^{i\theta}}\,\frac{\sin\theta}{a^2+b^2-2ab\cos\theta}$$

$$(u_\theta)_s = ie^{i\theta}(u-iv)_s = -\frac{mb}{\pi}\,\frac{\sin\theta}{a^2+b^2-2ab\cos\theta}$$

(iii) Maximum $|u_\theta|$ will now be at $\theta < \pi/2$ (since $(u_\theta)_s$ peaks ~~for~~ for $\theta < \pi/2$, thanks to decreasing denominator as θ decreases), suggesting that separation will be delayed. However, $\theta = 0$ is still a stagnation point, so severe adverse pressure gradients will be encountered at some point. The hope of eliminating separation will remain unfulfilled.

(c) Any sink away from the surface of the cylinder will be subject to the issue outlined in b(ii). However, suction on the cylinder surface at $\theta = 0$ would allow the surface velocity to increase continuously as the flow passes over the rear half of the cylinder, and could thus result in fully attached flow.

$\boxed{2-1}$

(a) $\zeta = z + \dfrac{a^2}{z} = Re^{i\beta} + \dfrac{a^2}{R} e^{-i\beta}$

So $x = \left(R + \dfrac{a^2}{R}\right) \cos\beta$

$y = \left(R - \dfrac{a^2}{R}\right) \sin\beta$

and thus $\dfrac{x^2}{b_x^2} + \dfrac{y^2}{b_y^2} = 1$, with $b_x = R + \dfrac{a^2}{R}$

$b_y = R - \dfrac{a^2}{R}$

(b) If $F_e(\zeta)$ is the complex potential for the flow around the ellipse, then

$$F_e(\zeta) = U\left(z(\zeta) + \frac{R^2}{z(\zeta)}\right)$$

[$F_e(\zeta) \simeq U\zeta$ far away and $\mathrm{Im}(F_e) = \text{constant}$ on ellipse]

$$(u - iv)_\zeta = \frac{dF_e}{d\zeta} = \frac{dF_e/dz}{d\zeta/dz} = U \frac{1 - R^2/z^2}{1 - a^2/z^2}$$

On the surface, $z = Re^{i\beta}$: $u - iv = U \dfrac{1 - e^{-i2\beta}}{1 - a^2/R^2\, e^{-i2\beta}}$

$$q^2 = (u-iv)(u-iv)^* = \frac{U^2(1 - e^{-i2\beta})(1 - e^{i2\beta})}{(1 - a^2/R^2\, e^{-2\beta i})(1 - a^2/R^2\, e^{2\beta i})}$$

$$= \frac{4\sin^2\beta}{1 + \frac{a^4}{R^4} - 2\frac{a^2}{R^2}\cos 2\beta} = \frac{4\sin^2\beta}{\left(1 - \frac{a^2}{R^2}\right)^2 + \frac{4a^2}{R^2}\sin^2\beta}$$

c) (i) $\sin\beta = \sin\varepsilon \approx \varepsilon$; $\cos\beta = -\cos\varepsilon \simeq -1 + \frac{\varepsilon^2}{2}$

$$\left.\begin{aligned} x &\approx -(R + a^2/R) \quad \text{constant} \\ y &\approx \left(R - \frac{a^2}{R}\right)\varepsilon \end{aligned}\right\} \quad s \approx R\left(1 - \frac{a^2}{R^2}\right)\varepsilon$$

$$q = \frac{U \; 2\sin\beta}{\sqrt{\left(1-\frac{a^2}{R^2}\right)^2 + \frac{4a^2}{R^2}\sin^2\beta}} \simeq \frac{2U\varepsilon}{1 - a^2/R^2}$$

(ii) $$\theta^2 = 0.45\nu\left(\frac{2U\varepsilon}{1-a^2/R^2}\right)^{-6}\int_0^{\varepsilon}\left(\frac{2U\varepsilon'}{1-a^2/R^2}\right)^5 R\left(1-\frac{a^2}{R^2}\right)d\varepsilon'$$

$$= \frac{0.45\nu R \left(1-\frac{a^2}{R^2}\right)^2}{2U\varepsilon^6}\int_0^{\varepsilon}[\varepsilon']^5\,d\varepsilon'$$

$$= 0.0375\,\frac{\nu R}{U}\left(1-\frac{a^2}{R^2}\right)^2$$

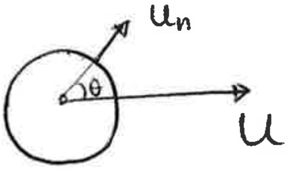
(iii) Notable features:

- θ is independent of $\varepsilon \Rightarrow$ constant near stagnation point;
- $\theta \propto 1 - \frac{a^2}{R^2}$, 'bluffer' ellipes (large R) give more intial momentum deficit;
- $\left(\frac{\theta}{R}\right)^2 \propto \left(\frac{UR}{\nu}\right)^{-1}$; momentum thickness as a proportion of body size decreases like $(\text{Reynolds number})^{-1/2}$

$\boxed{3-1}$

(a) Velocity $\perp$ to sphere surface must match between rigid-body and flow field.

Rigid-body motion



$u_n = U\cos\theta$

Doublet with $\mu = 2\pi a^3 U$: $u_r = U \frac{a^3}{r^3} \cos\theta$

Doublet coincides with sphere center

$\Rightarrow$ $r = a$ is the sphere surface, where $u_r = U\cos\theta = u$

Hence flow motion matches surface boundary condition.

Furthermore, the fluid velocity $\to 0$ at infinity, as required

(b) (i) Although the velocity of the sphere surface boundary condition is steady, its location varies with time. Alternatively, note that the flow field relative to the sphere is steady, so it cannot also be time-invariant in the frame of reference with the fluid stationary and the sphere moving.

(ii) Velocities at the sphere surface: $u_r = U\cos\theta$, $u_\theta = \frac{U}{2}$,

$\Rightarrow$ $|\underline{u}| = U^2 (\cos^2\theta + \frac{1}{4}\sin^2\theta)$

Potential: $\phi = -\frac{U a^3 \cos\theta}{2r^2} = -\frac{U a^3}{2} \frac{x - x_d}{[(x-x_d)^2 + y^2 + z^2]^{3/2}}$ with $\dot{x}_d = ($

$$\frac{\partial\phi}{\partial t} = -\frac{Ua^3}{2r^3}\left[-U + \frac{3}{2}\cdot 2\frac{(x-x_d)^2 U}{r^2}\right] = \frac{U^2a^3}{2r^3}\left[1-3\cos^2\theta\right]$$

On sphere surface: $\frac{\partial\phi}{\partial t} = \frac{U^2}{2}\left[1-3\cos^2\theta\right]$

(b) (ii) Bernoulli, ignoring gravitational terms, gives

$$\frac{p}{\rho} + \frac{1}{2}U^2\left(1-2\cos^2\theta + \frac{1}{4}\sin^2\theta\right) = \text{const}$$

$$\frac{p}{\rho} + \frac{U^2}{2}\left(-1 + \frac{9}{4}\sin^2\theta\right) = \text{const}$$

At $\theta = 0$ $p = p_0$ $\frac{p_0}{\rho} - \frac{U^2}{2} = \text{const}$

$$\Rightarrow p = p_0 - \frac{9}{8}\rho U^2 \sin^2\theta$$

(iii) $\sin(\pi-\theta) = \sin\theta$, so front & back pressures balance, and horizontal pressure force is zero.

(c) (i) Extra contribution to $\frac{\partial\phi}{\partial t}$ is $-\frac{\dot{U}a^2}{2r^2}\cos\theta = -\frac{\dot{U}a}{2}\cos\theta$

Additional pressure-field component is $\frac{1}{2}\rho\underline{\underline{\dot{U}}}a\cos\theta$

(ii) Integrate over circles of radius $a\sin\theta$

$$F_x = \int_0^{\pi} -p\cos\theta \cdot 2\pi a\sin\theta \cdot a\,d\theta = \rho\pi a^3\dot{U}\int_0^{\pi}\cos^2\theta(-\sin\theta)\,d\theta$$

$$= -\frac{2}{3}\rho\pi a^3\dot{U}$$

(iii) $F_x \propto$ acceleration, so can be interpreted as added mass of $\frac{2\pi}{3}\rho a^3$.

(a) For high Reynolds number flows, $Re \gg 1$,

$\delta \ll L$, or $\frac{\delta}{L} \ll 1$.

(b) ~~two~~ horizontal velocity u: scale U.
horizontal distance x: scale L.
vertical distance y: scale δ.

so $\frac{\partial u}{\partial x} \sim \frac{U}{L}$

$\frac{\partial u}{\partial y} \sim \frac{U}{\delta}$

(c) $\frac{\partial u}{\partial x} \sim \frac{U}{L}$, $\frac{\partial v}{\partial y} \sim \frac{\alpha}{\delta}$ where α is the scale of v.

Continuity equation: $\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0$

$$O\left[\frac{U}{L}\right] \quad O\left[\frac{\alpha}{\delta}\right]$$

α must be of order

$$\alpha \sim \frac{\delta}{L} U$$

(d) y-momentum equation

$$u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} = -\frac{1}{\rho}\frac{\partial p}{\partial y} + \nu\frac{\partial^2 v}{\partial x^2} + \nu\frac{\partial^2 v}{\partial y^2}$$

$$O\left[U\frac{1}{L}\frac{\delta}{L}U\right] \quad O\left[\frac{\delta}{L}U\frac{1}{\delta}\frac{\delta U}{L}\right] \quad O\left[\frac{P}{\rho\delta}\right] \quad O\left[\frac{\nu}{L^2}\frac{\delta}{L}U\right] \quad O\left[\frac{\nu}{\delta^2}\frac{\delta}{L}U\right]$$

Reorganizing the orders into nondimensional form produces

$$O\left[\left(\frac{\delta}{L}\right)^2\right] + O\left[\left(\frac{\delta}{L}\right)^2\right] = O\left[\frac{P}{\rho U^2}\right] + O\left[\frac{1}{Re}\left(\frac{\delta}{L}\right)^2\right] + O\left[\frac{1}{Re}\right]$$

Pressure scale is the inviscid scale ρU^2 and we have the following orders as $Re \to \infty$

$$O[0] + O[0] = O[1] + O[0] + O[0]$$

Thus, only one term is of order one, and the boundary layer y-momentum equation reduces to

$$0 = \frac{\partial p}{\partial y} \Rightarrow p = p(x).$$

The pressure is constant across the boundary layer. It means that pressure forces on a body are solely the result of the inviscid flow. They are not modified by the boundary layer.

The lift force on an airfoil is a direct result of pressure forces. At high Reynolds numbers the boundry layer become so thin that the pressure forces, and hence the lift force, are determined by the inviscid flow. Further increase in the Reynolds number will not change the lift force.

(e) x-momentum equation

$$u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} = -\frac{\partial p}{\partial x} + \nu\frac{\partial^2 u}{\partial x^2} + \nu\frac{\partial^2 u}{\partial y^2}$$

$$O\left[\frac{U^2}{L}\right] + O\left[\frac{\delta}{L}U\frac{U}{\delta}\right] = O\left[\frac{1}{\rho}\frac{\rho U^2}{L}\right] + O\left[\frac{\nu}{L^2}U\right] + O\left[\frac{\nu}{\delta^2}U\right]$$

Clearing U^2/L so that the terms are nondimensional produces

$$O[1] + O[1] = O[1] + O\left[\frac{1}{Re}\right] + O\left[\left(\frac{\delta}{L}\right)^{-2}\frac{1}{Re}\right]$$

The last term is indeterminate

$$\frac{1/Re}{(\delta/L)^2} \sim \frac{0}{0} \rightarrow ?$$

① If $\frac{1/Re}{(\delta/L)^2} \rightarrow 0$ as $Re \rightarrow \infty$, we are left with the same momentum equation as for the inviscid flow. Not good

② $\frac{1/Re}{(\delta/L)^2} \rightarrow \infty$ as $Re \rightarrow \infty$, for this case the momentum equation becomes $0 = \frac{\partial^2 u}{\partial y^2}$, or $u = C_1(x)y + C_2(x)$.

Boundary condition $\xrightarrow{u=0 \text{ at } y=0}$ $C_2 = 0$. Boundary layer ~~velocity~~ has a linear velocity profile. Such a solution will not smoothly match inviscid flow. Not good

The last possibility is the ratio $\frac{1/Re}{(\delta/L)^2}$ is finite,

that is $\frac{\delta}{L} \sim \sqrt{\frac{1}{Re}}$

Therefore the momentum equation for the boundary layer is $u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} = -\frac{\partial p}{\partial x} + \nu\frac{\partial^2 u}{\partial y^2}$.

(a) At the wall

$$\nu\left(\frac{\partial^2 u}{\partial y^2}\right)_w = \frac{1}{\rho}\frac{dP}{dx} = -U\frac{dU}{dx}$$

$$m = \frac{\theta^2}{U}\left(\frac{\partial^2 u}{\partial y^2}\right)_w = -\frac{\theta^2}{\nu}\frac{dU}{dx}$$

(b) Momentum integral equation

$$\frac{d\theta}{dx} + (2+H)\frac{\theta}{U}\frac{dU}{dx} = \frac{C_f}{2} = \frac{\tau_w}{\rho U^2}$$

multiplied by $\frac{U\theta}{\nu}$,

$$U\frac{d\theta^2}{dx} = 2\nu\left[m(H+2)+l\right] = \nu L(m)$$

(c)

$$U\frac{d(\theta^2)}{dx} = 0.45 - 6\theta^2\frac{dU}{dx}$$

or

$$\frac{d}{dx}(U^6\theta^2) = 0.45\,\nu U^5$$

Integrate this equation from the leading edge to x_1, we have

$$[\theta^2]_{\text{at } x_1} = \frac{0.45\nu}{U^6_{(x_1)}}\int_0^{x_1} U^5_{(x)}\,dx$$

(d)

$$\theta^2 = \frac{0.45\nu}{U_0^6(1-x/L)^6}\int_0^x U_0^5\left(1-\frac{x}{L}\right)^5 dx$$

$$= 0.075\frac{\nu L}{U_0}\left[\left(1-\frac{x}{L}\right)^{-6} - 1\right]$$

(e) $$m = -\frac{\theta^2}{\nu}\frac{dU}{dx} = 0.075\left[\left(1-\frac{x}{L}\right)^{-6} - 1\right].$$

Given $m(x)$, the separation point is predicted by

$$m = 0.09 = 0.075\left[\left(1-\frac{x_{sep}}{L}\right)^{-6} - 1\right]$$

$$\frac{x_{sep}}{L} = 1-(2.2)^{-1/6} = 0.123$$

$$x_{sep} = 0.123$$

Pressure coefficient

$$c_p = \frac{p-p_0}{\frac{1}{2}\rho U_0^2} = 1-\left(\frac{U}{U_0}\right)^2 = 0.233$$

at separation

This illustrate the relative small pressure increase that can be sustained by a laminar boundary layer before separation,

(a) Camber line $y_c = h\frac{x}{c}\left(1-\frac{x}{c}\right)\left(k-\frac{x}{c}\right)$

$$g_0 + \sum_{n=1}^{\infty} g_n \cos(n\theta) = -\left.\frac{2\,dy_c}{dx}\right|_{\theta}$$

$$\therefore \frac{dy_c}{dx} = \frac{h}{c}\left[k - 2(1+k)\frac{x}{c} + 3\left(\frac{x}{c}\right)^2\right]; \quad x = \frac{c}{2}(1+\cos\theta)$$

$$= \frac{h}{c}\left[k - (1+k)(1+\cos\theta) + \frac{3}{4}(1+\cos\theta)^2\right]$$

$$\therefore 2\frac{dy_c}{dx} = \frac{h}{c}\left[\frac{1}{4} + (1-2k)\cos\theta + \frac{3}{4}\cos 2\theta\right.$$

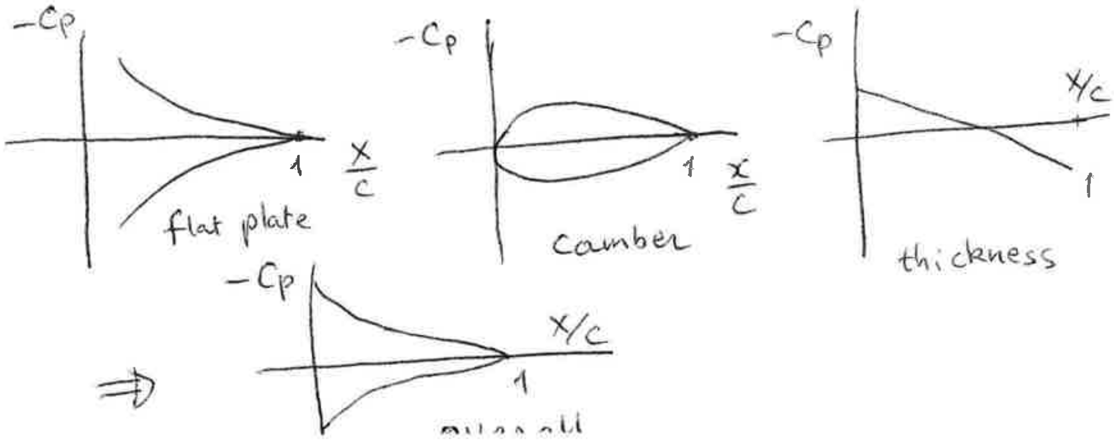
$$\therefore g_0 = -\frac{1}{4}\frac{h}{c}, \quad g_1 = (2k-1)\frac{h}{c}, \quad g_2 = -\frac{3}{4}\cdot\frac{h}{c}$$

(b) $$\gamma(\phi) = -U\left[g_0\frac{1-\cos\phi}{\sin\phi} + \sum_{n=1}^{\infty} g_n \sin(n\phi)\right]$$

$$\Delta p = P_{lower} - P_{upper} = -\rho U \gamma$$

$$\therefore \frac{\Delta P}{\frac{1}{2}\rho U^2} = \underbrace{-\frac{1}{8}\cdot\frac{h}{c}\cdot\frac{1-\cos\phi}{\sin\phi}}_{\text{flat plate solution}} + \underbrace{\frac{2k-1}{2}\cdot\frac{h}{c}\cdot\sin\phi - \frac{3}{8}\frac{h}{c}\cdot\sin 2\phi}_{\text{camber solution}}$$

(c)



(d) The camber load is at a maximum when

$$\frac{d}{dx}\left[\frac{2K-1}{2} \cdot \frac{h}{c} \cdot \sin\phi - \frac{3}{8}\frac{h}{c} \cdot \sin 2\phi \right] = 0$$

ie,
$$(2K-1)\cos\phi \frac{1}{\cancel{-\frac{c}{2}\sin\phi}} - \frac{3}{4}\, 2\cos 2\phi \frac{1}{\cancel{-\frac{c}{2}\sin\phi}} = 0$$

$$(2K-1)\cos\phi = \frac{3}{2}\cos 2\phi$$

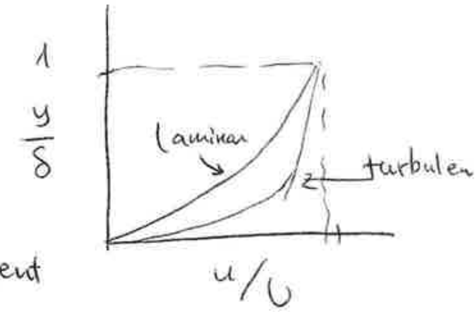
So far max load due to camber at $\frac{x}{c} = \frac{1}{4}$

Hence $(2K-1)\left(-\frac{1}{2}\right) = \frac{3}{2}\left(2\left(-\frac{1}{2}\right)^2 - 1\right)$

$$2K - 1 = 3/2$$

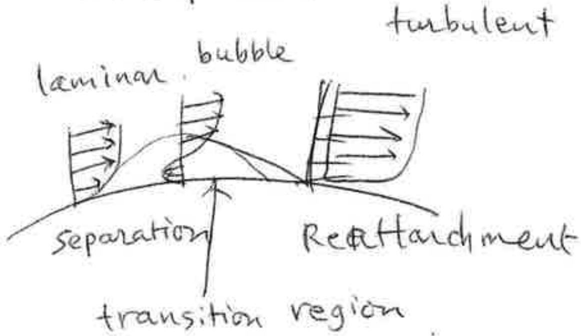
$$\underline{K = 5/4}$$

(a) Turbulent b'layers are dominated by unsteady mixing processes and are thicker and fuller in profile than laminar layers

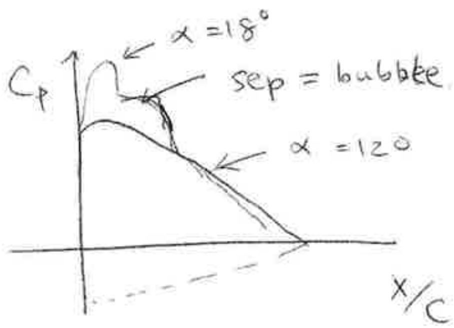


separation occurs when a b' layer is subjected to adverse pressure gradients. Turbulent layers, with their fuller profile, are less prone to separation than laminar. Transition from laminar to turbulent is inhibited by favorable and encouraged by adverse pressure gradients.

(b) When the near-wall velocity is unable to support the adverse pressure gradient then separation can occur.



Often on airfoils laminar separation is followed by turbulent reattachment (a separation bubble) visible as a flat in the Cp plot.



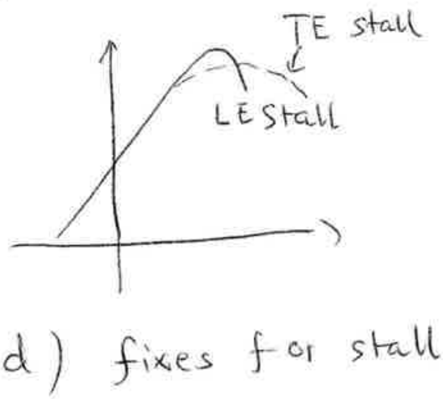
(c) At high Reynolds numbers there are two main types of stall:

(i) leading edge stall

(ii) trailing edge stall

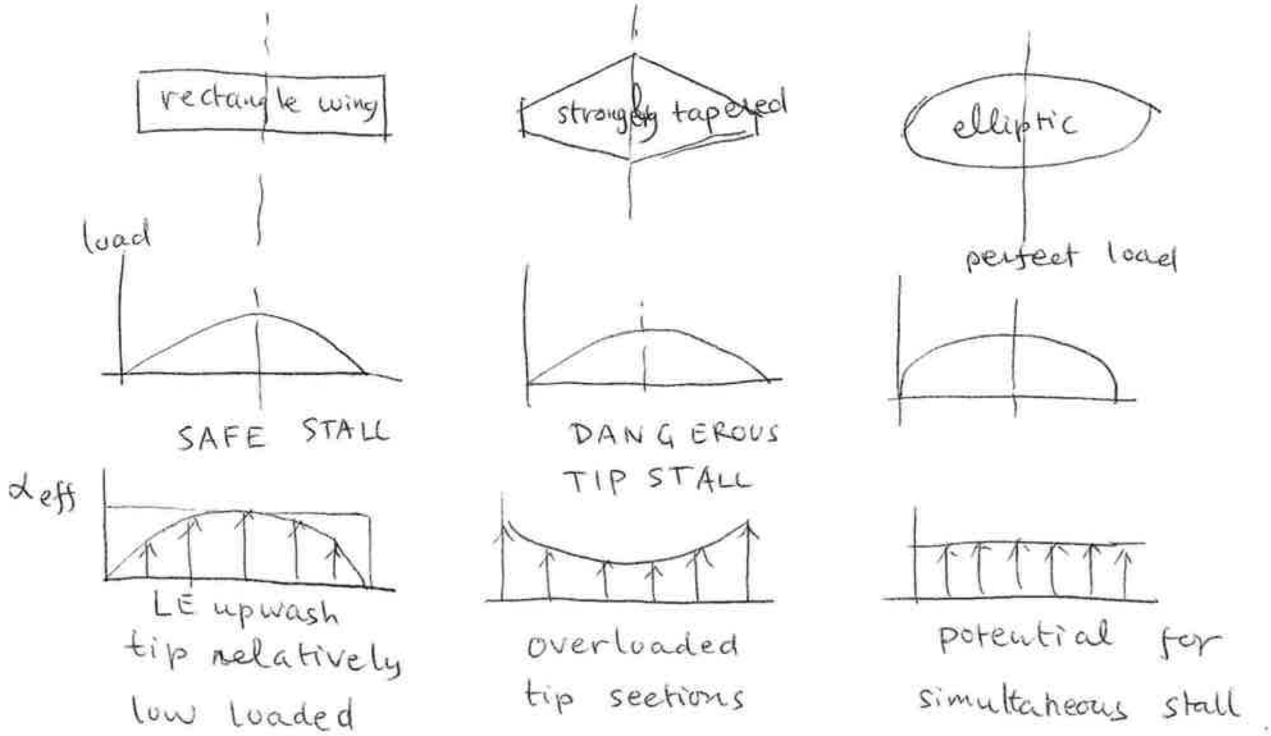
Leading edge stall is typically associated with thin airfoils and is linked to the separation bubble which forms after the suction peak as the angle of attack is increased. Eventually the bubble bursts and abrupt stall takes places.

Trailling edge stall is typically associated with thick airfoils and occurs when the $\underbrace{\text{cumulative}}$ effect of the suction side adverse pressure gradient causes a separation to start near the trailing edge and then move progressively upstream as the angle of attack increases leading to gradual stall



(d) fixes for stall are based on re-energising the new-wall b'layer in save way and use combinations of vortex genelators, tribulations blowing and suction.

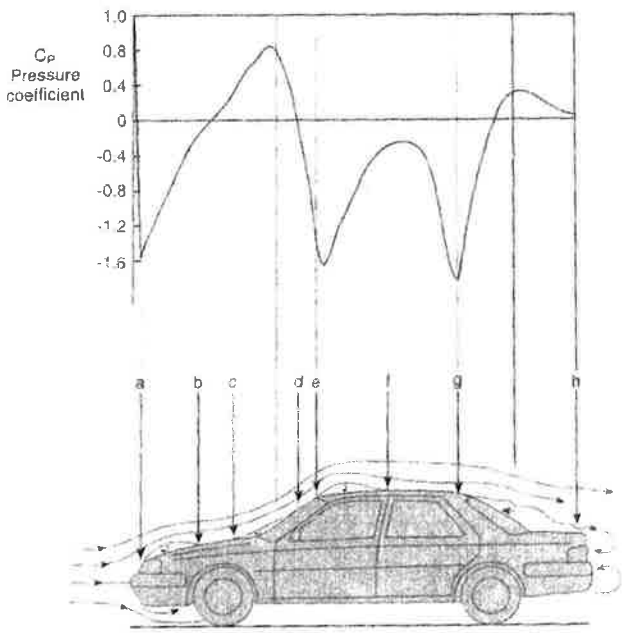
(e) The spanwise loading distribution, manipulation by geometric washout or wing platform or section lifting characteristics has a strong rolle in stalling behavior.



(f) B'layer cross-flow takes place on swept wings as b'layer fluids deflect with greater curvature than free-stream fluid in the same spanwise pressure gradient [$\frac{\partial p}{\partial r} \sim \rho \frac{v^2}{r} \sim \rho \frac{V^2}{R}$] so $v < V$, $r < R$]. On a finite wing this leaves to the accumulation of low enegy fluid towards the wing tips – this leads to a greater succeptibilit to stall near the tip. This can be controlled to some extent by installing "chordwise b'layer fences".

a) see picture below (taken from Fig 4.21 in "Road vehicle aerodynamic design", R.H. Barnard). Somewhat simpler pressure distributions are also acceptable as long as they feature:

- suction peaks at the corners of: front boot lid, roof front edge and roof rear edge and possibly at the rear boot lid edge (but the flow is likely to separate here which would remove local suction). Note that, for better designed cars the suction peak at the rear of the roof may not be prominent (see Audi image later). In that case there would be no separation.
- high pressures at: nose (stagnation point above A), lower front windscreen corner, lower edge of rear windscreen corner
- approximately constant pressure in the separated region at the rear (between rear boot lid corner and B)



Centre-line pressure distribution and flow features of a simple three-box form vehicle.

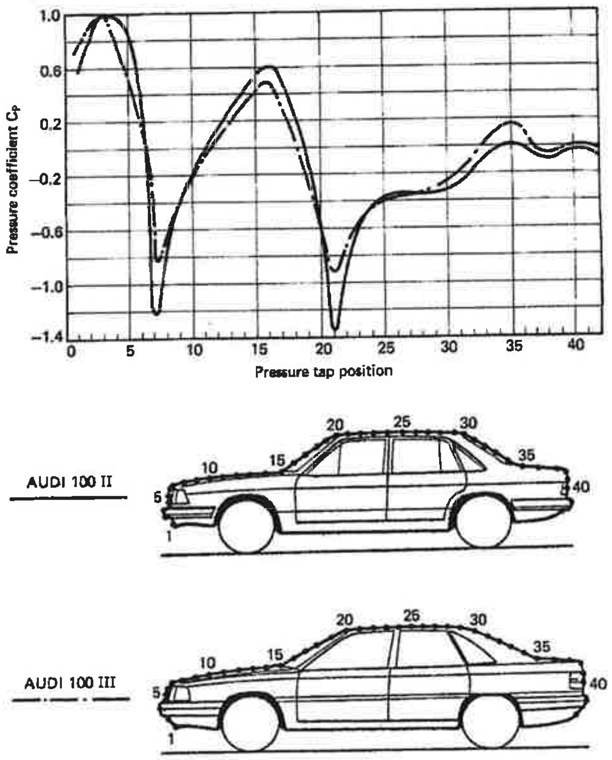
b) Potential separated zones are:

- leading edge of the hood – this is likely to increase drag by a small/medium amount (separation bubble of limited extent)
- enclosed separation bubble at the hood-windscreen junction – this has only a small drag contribution
- separation bubble at leading edge of roof (if the edge is sharp
- separation behind the rear roof edge (at rear window) – this is unlikely to re-attach and would cause significant drag
- separation at boot lid (unless the flow is already separated at the rear window), this is the main drag contribution (but somewhat unavoidable)

c) Many suggestions can be found in the notes. In particular:

- rounding off of nose (front boot-lid) and roof edges
- increasing front window slant – rounding off junction (but keep in mind that wipers will ad to drag)
- reduce the sweep angle of the rear window to about 20deg for best drag performance and ensure that the roof-rear window junction is rounded. This may require the boot lid to be raised to avoid the car from becoming too long or turning into a fastback.
- Change boot lid contour to have a degree of boat-tailing (downward sweep) this will reduce the base area and increase base pressure, both of which is good for drag.

See below for an example of a relatively old car (Audi 100) suffering from a 'peaky' pressure distribution and note how rounding off some of the corners has eased off the adverse pressure gradients and removed the danger of separation:



d) See notes. Potential suggestions are:
Hide wipers from flow behind a deflector (reduces form drag)
Boat-tailing of the sides (reduces base drag by increasing base pressure and reducing wake area)
Underbody diffuser at rear (acts similar to boat-tailing but watch for separation)
Cover wheels (like some low drag cars)
Apply front spoiler to reduce flow on underside and onto the wheels
Downward slant of boot lid (to give a bit more boat-tailing) with a small separation lip at the rear edge (to slightly raise base pressure)
...