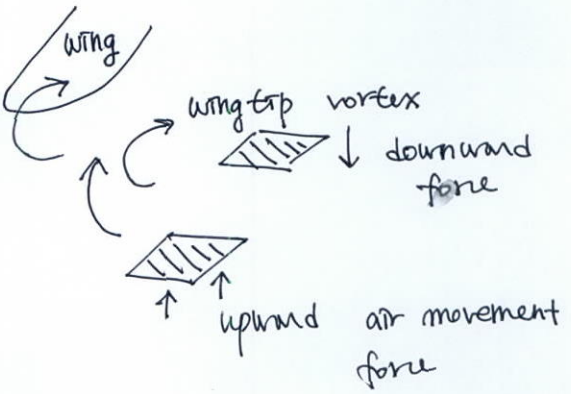
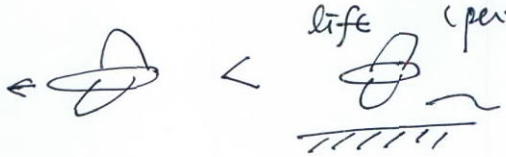


- fish schooling

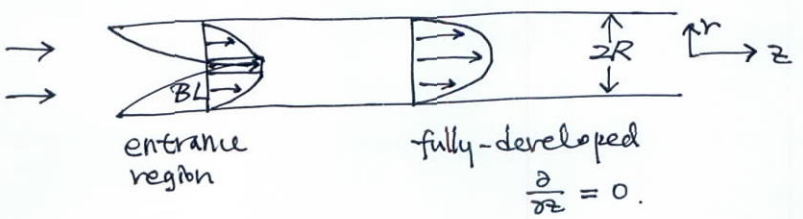
(2) Ground effect



increases air pressure on the lower wing surface

interrupts wingtip vortices → lower induced drag

Chap. 13. Flows within pipes and other structures



Navier-Stokes eq (cyl. coords)

$$\rho \frac{Dv_z}{Dt} = -\frac{\partial p}{\partial z} + \mu \left[\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial}{\partial r}\right) + \frac{1}{r^2}\frac{\partial^2}{\partial \theta^2} + \frac{\partial^2}{\partial z^2}\right] v_z$$

$$\rightarrow \quad 0 = -\frac{dp}{dz} + \mu \frac{1}{r}\frac{d}{dr}\left(r\frac{d}{dr}\right) u$$

B.C. $\quad u(r = R) = 0$

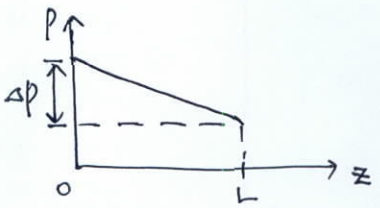
$$\frac{du}{dr}(r=0) = 0.$$

$$u = \left(-\frac{dp}{dz}\right)\frac{1}{4\mu}(R^2 - r^2)$$

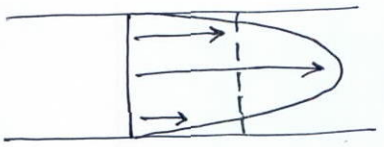
$$-\frac{dp}{dz} = \frac{\Delta p}{L}$$

$$Q = \int_0^R u\,(2\pi r)\,dr$$

$$= \frac{\pi R^4}{8\mu}\left(\frac{\Delta p}{L}\right)$$

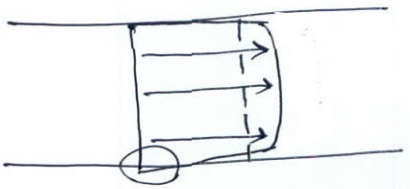


* Turbulent pipe flow



laminar . $f = \frac{64}{Re_d}$

(same u_{av})

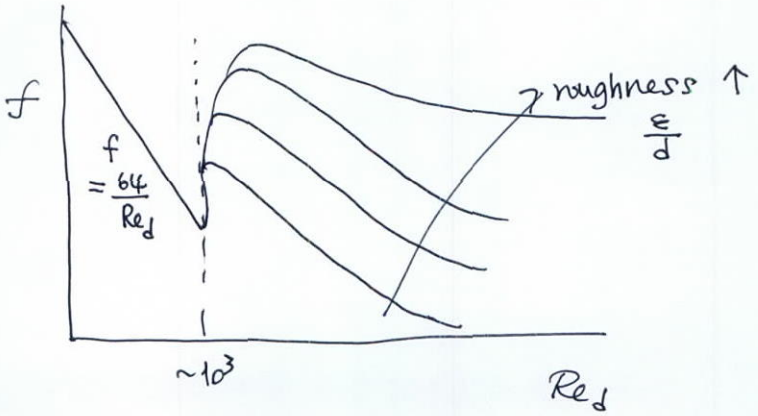


turbulent

higher vel. gradient → τ_w ↑

friction factor $= \frac{8\tau_w}{\rho u_{av}^2}$

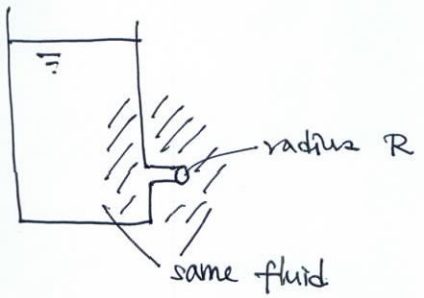
The Moody chart



* Resistance

$$R = \frac{\Delta p}{Q} = \frac{8\mu L}{\pi R^4}$$ (laminar)

§ Flow through circular apertures (submerged)



$Re < 3$: $Q = \frac{R^3 \Delta p}{3\mu}$

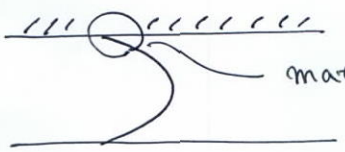
higher Re : $Q = C_0 \pi R^2 \left(\frac{2\Delta p}{\rho}\right)^{1/2}$

C_0 : orifice coefficient $= fn(Re_d)$

Chap. 14. Internal flows in organisms

- most circulatory systems of animals
  ~ pulsatile flow of non-Newtonian fluids in pipes of time varying cross-sectional areas and shapes

§ Circumventing the parabolic profile

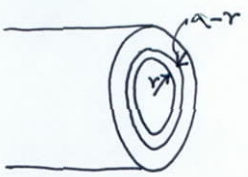


material/heat exchange ~ $\frac{\partial u}{\partial y}$ ↓ when parabolic

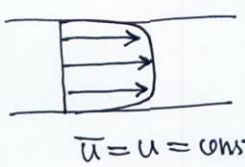
(1) How far is flow from a wall ?

- distance index

$$D_i = \frac{1}{\pi a^2 \bar{u}} \int_0^a u(a-r) \cdot 2\pi r \, dr \quad / a$$



① plug flow (slug flow)



$\bar{u} = u = \text{const.}$

$$D_i = \frac{2\pi}{\pi a^2 u} u \int_0^a (ar - r^2) \, dr$$

$$= \frac{2}{a^3} \cdot \left(\frac{a^3}{2} - \frac{a^3}{3}\right) = \frac{1}{3}$$