Chapter 6: Viscous flows in Ducts

: lam   : Tur

- There are three types of flows: (Depending on Re number)
  - 1- laminar flow: At low Re :- The flow is smooth
    the viscosity is high

    $Re \leq 1000$

  - 2- $1000 \leq Re \leq 10000$ transition to turbulence
  - 3- Turbulent flow: At high Re
    low . viscosity

    $Re \geq 10000$

Raynolds number:

$$Re = \frac{\rho V d}{\mu}$$

or

$$Re = \frac{Vd}{\nu}$$

V: Average velocity

ν: Kinematic viscosity

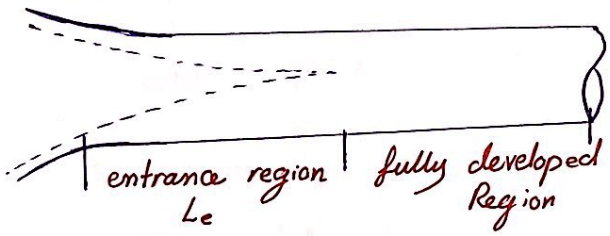
$Re_{critical} = 2300$

Difference between internal and external flow

- → Internal: بكون محدود بسطح صلب والحدود واضحة
- → external: بكون مش محدود زي ال flow حول الطائرة

- Note: we only study internal flows (Bounded)

- In Internal flows :-



→ For laminar flow: $\frac{L_e}{d} \approx 0.06\, Re$ (Max $l_e = 138d$ at critical Re)

→ For Turbulent flow: $\frac{L_e}{d} \simeq 1.6\, Re^{1/4}$ for $Re \leq 10^7$

Note: Turbulent pressure drops with diameter more than laminar so to decrease pumping pressure use larger pipes

Head loss The friction factor

$$\left(\frac{P}{\rho g}+\frac{\alpha V^2}{2g}+z\right)_1=\left(\frac{P}{\rho g}+\frac{\alpha V^2}{2g}+z\right)_2+h_f \Rightarrow h_f=\Delta z+\frac{\Delta P}{\rho g}$$

if V is constant

$$h_f=f\frac{L}{d}\frac{V^2}{2g}$$

دلتي آ موجود
Df اذا كانت Bernouli

and we can relate head loss to wall shear stress

$$h_f=\frac{4\tau_w L}{\rho g d}$$

- **For laminar flow**:- $h_f=\dfrac{32\mu L V}{\rho g d^2}=\dfrac{128\mu L Q}{\pi\rho g d^4}$

$$f=\frac{64}{Re}$$

- **For turbulent flow**: $\dfrac{1}{\sqrt{f}}=-1.8\log\left(\left(\dfrac{\epsilon/d}{3.7}\right)^{1.11}+\dfrac{6.9}{Re}\right)$

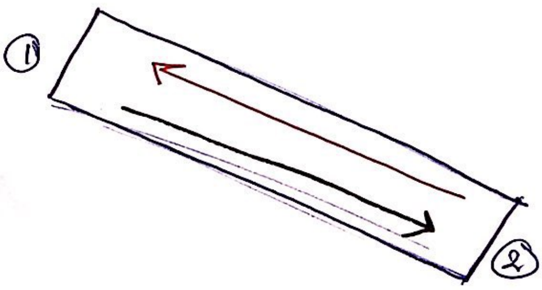
or you can use moody chart

- **Remember**:

$h_f=\Delta HGL$

where $HGL=z+\dfrac{P}{\rho g}$ if V is constant

flow Goes from higher HGL to low HGL



so if $HGL_1 < HGL_2$

Then flow is $2\rightarrow 1$

if $HGL_1 > HGL_2$

Then flow is $1\rightarrow 2$

Scanned with CamScanner

- four Types of pipe flow problems

Type 1: Given: d, L, V or Q, ρ, μ and g

Find: h_f

solution: find Re, $\frac{\epsilon}{d}$ and find f then comput h_f

Type 2: Given: d, L, h_f, ρ, μ and g

Find: V or Q

solution: Direct:- calculate ζ, Then use relation

$$Re_d = (-8\zeta)^{\frac{1}{2}} \log\left(\frac{\epsilon/d}{3.7} + \frac{1.775}{\sqrt{\zeta}}\right)$$

(Not always right, it can be wrong if there are losses)

Iterative: Assume value of f and use the relation between f and V using $f = h_f \frac{d}{L} \frac{2g}{V^2}$

f is at the fully rough so ϵ/d is calculated then use eq* fully rough

$$* \quad \frac{1}{\sqrt{f}} = -2\log\frac{\epsilon/d}{3.7}$$

Type 3: Given: Q, L, h_f, ρ, μ and g

Find: diameter d

solution: find d in terms of f using $f = \frac{\pi^2}{8} \frac{g h_f d^5}{L Q^2}$

- find Re in terms of d

  → using $Re = \frac{4Q}{\pi d \nu}$

- find Ratio ϵ/d
- Guess f then find $\underbrace{\text{new Re, new Ratio}}$ use these to find f_{new}
- stop at convergance

Type 4: Given Q, d, h_f, ρ, μ and g

Find: pipe length L

Solution: If minor losses are neglected & pipe is horizontal

$$h_{pump} = \frac{Power}{\rho g Q} = h_f = f \frac{L}{d} \frac{V^2}{2g}$$

flow in Noncircular ducts

Hydraulic diameter

- $D_H = \dfrac{4 \times \text{Area}}{\text{wetted perimeter}}$ → المحيط

→ If the flow is between Parallel plates

$$D_H = 4h \qquad \text{where } h = \frac{\text{distance apart}}{2}$$

→ if the flow is laminar:

$$\tau_w = \frac{3\mu V}{h}$$

$$h_f = \frac{\Delta P}{\rho g} = \frac{3\mu L V}{\rho g h^2} \quad , \quad h_f = f\frac{L}{D_h}\frac{V^2}{2g}$$

$$f_{lam} = \frac{96}{Re_{D_h}} \quad , \quad Re = \frac{\rho V D_h}{\mu}$$

→ if the flow is turbulent

use D_h as laminar for reasonable accuracy

or use D_{eff} for more accuracy

$$D_{eff} = \frac{64}{96} D_h$$

Minor or local losses in Pipe systems

$$\Delta h_{tot} = h_f + \sum h_m = f \frac{V^2}{2g} \frac{L}{d} + \underbrace{\sum K}_{\downarrow} \frac{V^2}{2g}$$

Given or found from curves

Additional Notes:

In eq: $\left(\frac{P}{\rho g} + \text{---}\right)_1 = \left(\frac{P}{\rho g} + \cdots\right)_2 + h_f$

6.26 ✓
6.34
6.36
6.109 Pdf

- P is either Gage or absolute for Both sides

- In pumps

$$P = \frac{\rho g Q h_p}{\eta}$$

- original equation of losses

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + z_2 + h_f + \sum h_m - h_p$$

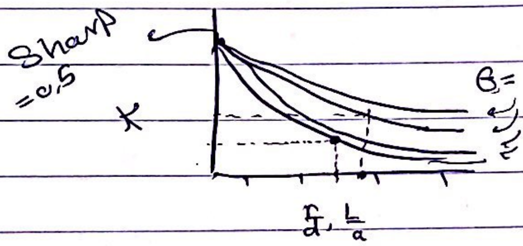
Given or found

$$\sum h_m \rightarrow \sum K \frac{V^2}{2g}$$

How to find K ?

Sharp exit : $K=1$

sharp entrance: go to fig 6.21 , $K=0.5$
if not sharp , cal $\frac{r}{d}$ or $\frac{l}{d}$ and then go vertical to the angle Given



open valve, elbows, Tees → Go to table 6.5 and
convert d (in m) to inch
choose the right diameter and read the value of K

$1\ m \approx 39.37$ inch

Bendings : Fig 6.20 , calculate $\frac{R}{d}$ ← radius of bend, → diameter

choose right angle (90, 180, 45)
and obtain K

half open valves , Gate or disk or Globe
go to fig 6.18 b
obtain: fractional opening $\frac{h}{D}$ then choose type and obtain K