Fluid Mechanics - MTF053 Lecture 10

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Chapter 6 - Viscous Flow in Ducts



Learning Outcomes

- 3 Define the Reynolds number
- 4 Be **able to categorize** a flow and **have knowledge about** how to select applicable methods for the analysis of a specific flow based on category
- 6 Explain what a boundary layer is and when/where/why it appears
- 8 **Understand** and be able to **explain** the concept shear stress
- 18 Explain losses appearing in pipe flows
- 19 Explain the difference between laminar and turbulent pipe flow
- 20 Solve pipe flow problems using Moody charts
- 24 Explain what is characteristic for a turbulent flow
- 25 Explain Reynolds decomposition and derive the RANS equations
- 26 Understand and explain the Boussinesq assumption and turbulent viscosity
 - 7 **Explain** the difference between the regions in a boundary layer and what is characteristic for each of the regions (viscous sub layer, buffer region, log region)
 - if you think about it, pipe flows are everywhere (a pipe flow is not a flow of pipes)

Roadmap - Viscous Flow in Ducts



These lecture notes covers chapter 6 in the course book and additional course material that you can find in the following documents

MTF053_Equation-for-Boundary-Layer-Flows.pdf

MTF053_Turbulence.pdf

"Piping systems are encountered in almost every engineering design and thus have been studied extensively"



Example I:

Given pipe geometry, fluid properties, flow rate, and locations of valves, bends, diffusers etc - estimate the pressure drop needed to drive the flow

Example II:

Given the pressure drop available from a pump - what flow rate can be expected

Roadmap - Viscous Flow in Ducts



Transition to Turbulence





Transition to Turbulence





Factors that affects the transition to turbulent flow:

- 1. Wall roughness
- 2. Fluctuations in incoming flow
- 3. Reynolds number

Transition to Turbulence

Reynolds number



Fluctuations in the fully turbulent flow velocity signal: typically 1% to 20% of the average velocity not periodic random

continuous range (spectrum) of frequencies

Transition to Turbulence



Transition to Turbulence - Viscous Flow in Ducts

Note! The ranges will vary somewhat with geometry and surface roughness

Transition to Turbulence - Viscous Flow in Ducts

An accepted design value for **pipe flow transition** is

 $Re_{d,crit} \approx 2300$

Note!



2. by careful design the Reynolds number can be pushed to higher values

Transition to Turbulence - Viscous Flow in Ducts

The great majority of our analyses are concerned with laminar flow or with turbulent flow, and one should not normally design a flow operation in the transition region.



Transition to Turbulence - Osborne Reynolds (1842-1912)



Wall-bounded flows - constrained by bounding walls

Boundary layers grows and meet at the center















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$$L_e = f(d, V, \rho, \mu)$$



$$V = \frac{Q}{A} = \frac{4Q}{\pi d^2}$$

а

$$Q = \int u dA = const$$

Dimensional analysis gives:

$$\frac{L_e}{d} = g\left(\frac{\rho V d}{\mu}\right) = g(Re_d)$$

Laminar flow:

 $\frac{L_e}{d} \approx 0.06 Re_d$

The maximum laminar entrance length, at $Re_d = Re_{d,crit} = 2300$, is $L_e = 138d$, which is the longest development length possible

Turbulent flow ($Re_d \leq 10^7$):

 $\frac{L_e}{d} \approx 1.6 \text{Re}_d^{1/4}$

<i>Re</i> _d	4.0×10^3	1.0×10^4	1.0×10^5	1.0×10^6	1.0×10^7
L _e /d	13	16	28	51	90
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