Design and Modeling of Fluid Power Systems

ME 597/ABE 591 - Lecture 3

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Contents

1. Introduction and overview of components, circuit and system design methods

2. Fluid properties, types of fluids, cavitation

3. Modeling of transmission lines, impedance model of lines, accumulators

4. Displacement machines design principles, flow and pressure pulsation

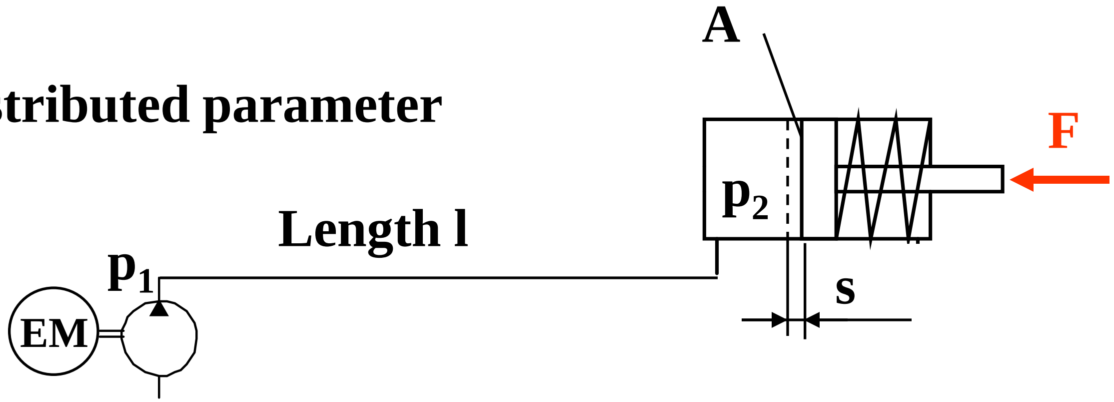
5. Steady state characteristics, measurement methods and modeling

6. Gap flow models

Modeling of transmission lines

Purpose of the model

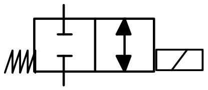
Lumped parameter versus distributed parameter



Pressure loss (type of flow)

$\Delta V = s \cdot A$

Transient pressure, p=f (time)



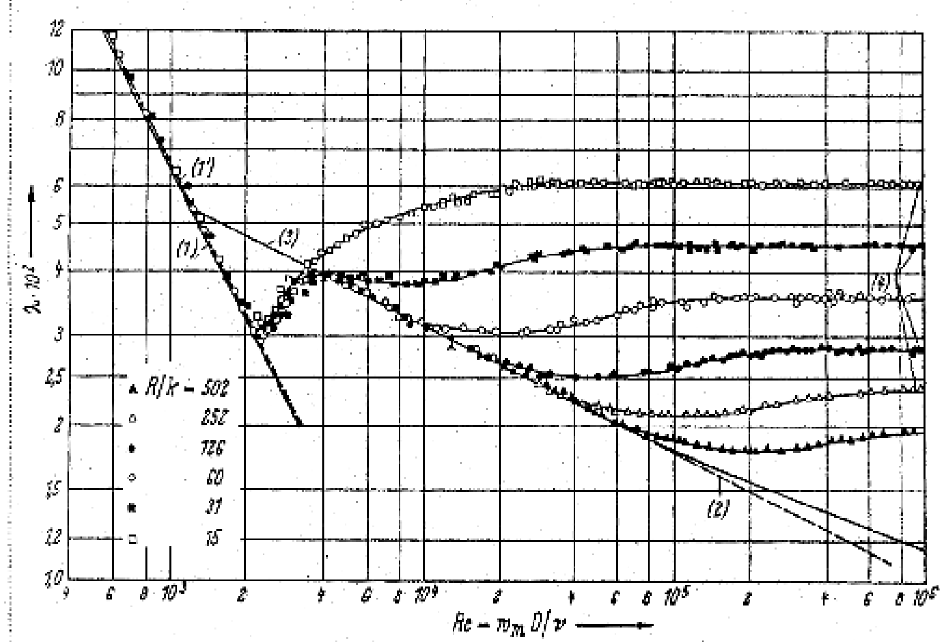
Fluid inertia

Pressure loss

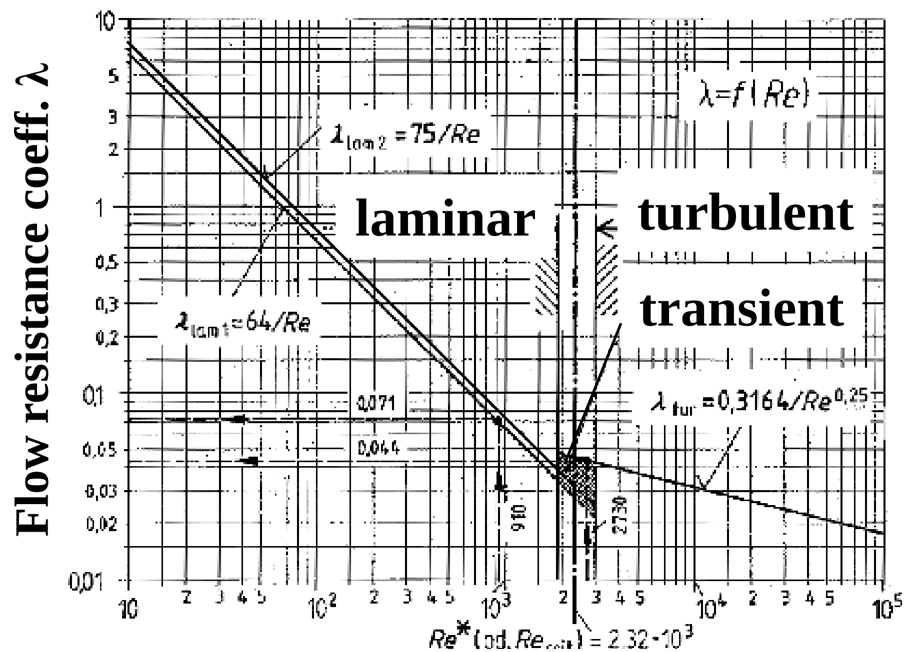
Flow resistance coefficient (friction factor) λ = f(Re)

@ high Re dependent on surface roughness

for hydraulically smooth pipes



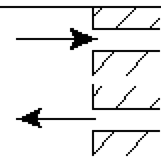
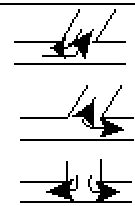
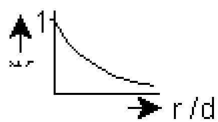
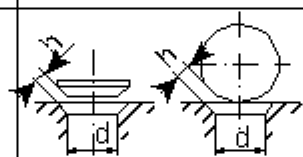
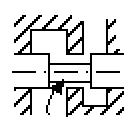
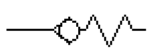
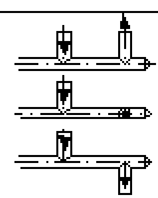
J.Nikuradse (Moody diagram)



Reynolds number Re

Pressure loss

Drag coefficient ξ - experimentally determined

Type	ξ	
Inlet Outlet	0,5 1	
Tee	0,5 3 1,3	
Bend		
Seat valve	2.5	
Spool Valve	8 - 16	
Check valve	3 - 10	
Double change of flow direction	1,5 1,8 2,3	

$$\Delta p_F = \sum_{i=1}^{k} \xi_i \cdot \rho \cdot \frac{v_i^2}{2}$$

Due to change of flow path in fittings, bends, valves

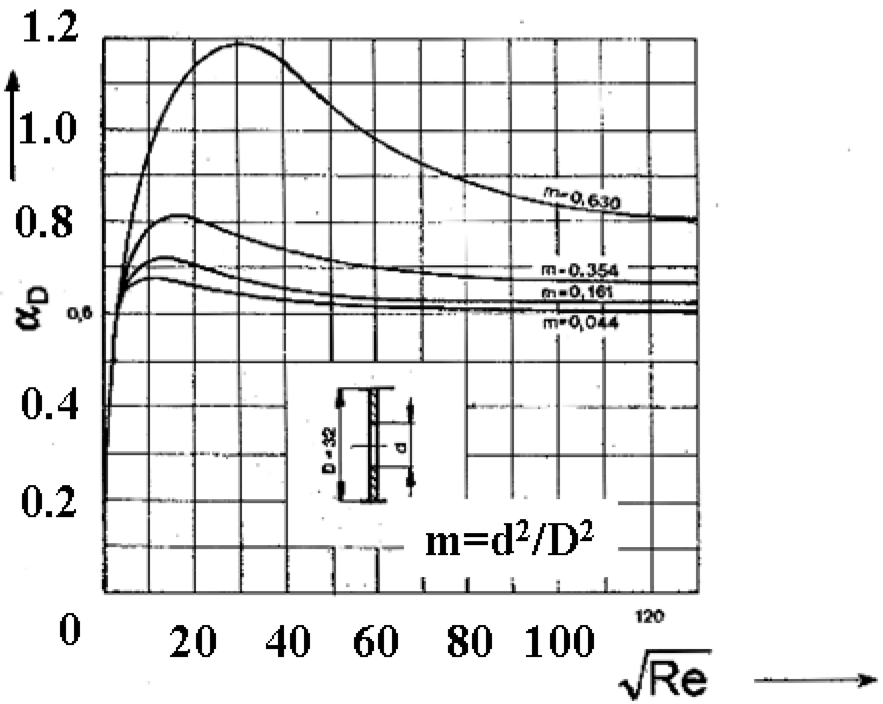
$$\Delta p_S = \Delta p_F + \Delta p_L$$

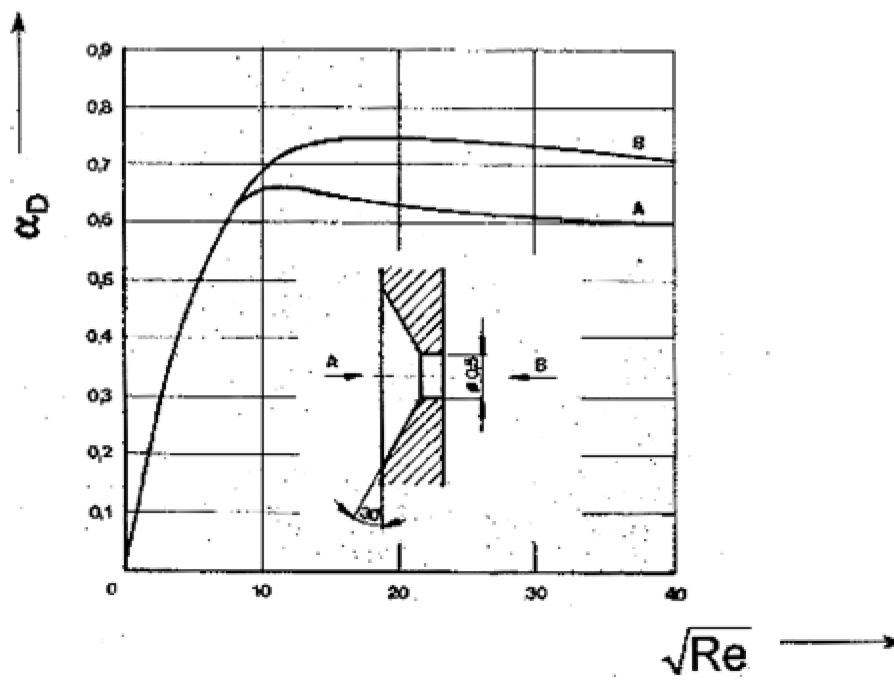
Pressure loss in hydraulic lines (pipes)

$$\Delta p_L = \sum_{j=1}^{m} \lambda_j \cdot \frac{l_j}{d_j} \cdot \rho \cdot \frac{v_j^2}{2}$$

Orifice Flow

α_D … Discharge coefficient





Hydraulic Accumulators

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Types of hydropneumatic accumulators (gas loaded)

Piston design

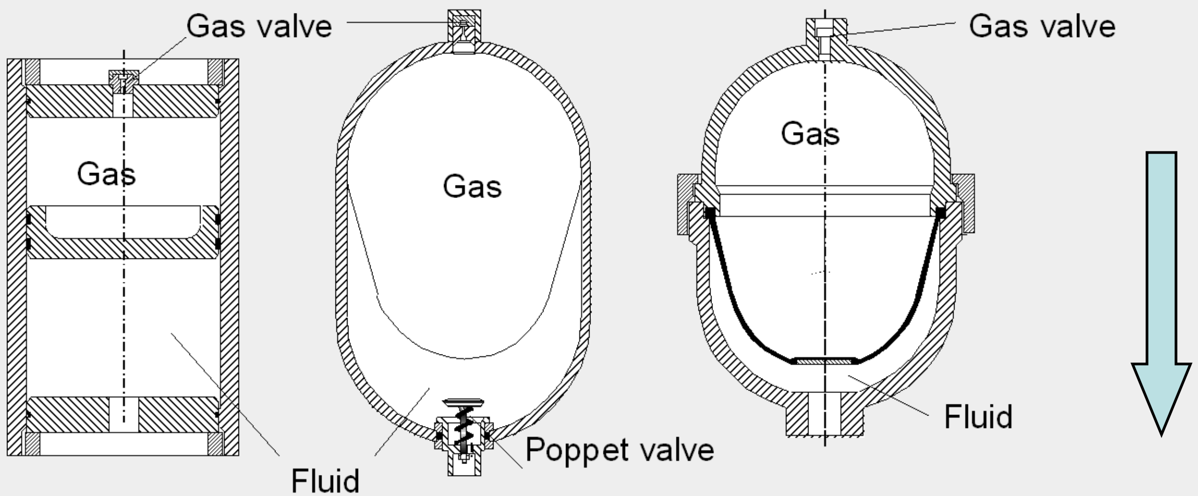
Bladder design

Diaphragm design

Screwed

Welded

Weight loaded



Piston exchangeable

Bladder exchangeable

Diaphragm exchangeable

Maintenance free

Gas used: ***Nitrogen***, Helium, Argon, Carbon dioxide

❸ large

❸ uncommon

❸ piston loaded design

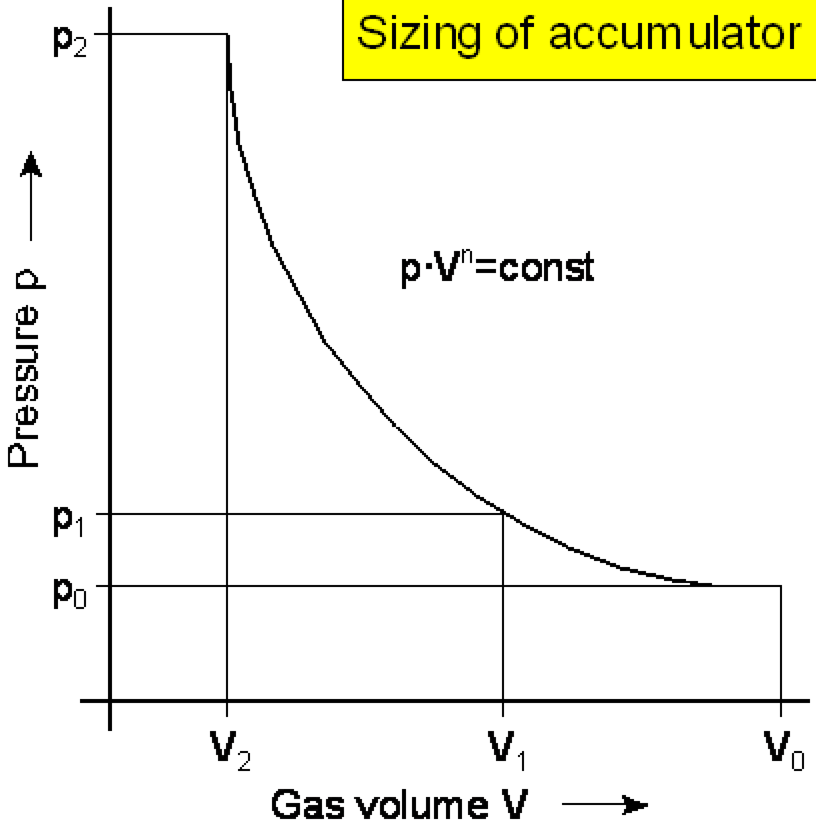
Advantage:

Maintain fluid pressure constant

Hydraulic Accumulators

Gas loaded

Sizing of accumulator & working principle



Thermodynamic process
→ adiabatic n=1.4
→ isothermal n=1

$$\Delta V = V_0 \left[\left(\frac{p_0}{p_1} \right)^{\frac{1}{n}} - \left(\frac{p_0}{p_2} \right)^{\frac{1}{n}} \right]$$

ΔV … **useable fluid volume**

V_0 … **size of the accumulator**

p_0 … precharge gas pressure $p_0 = 0.9\, p_1$
V_0 … effektive gas volume @ p_0