1D pipeline model

State equation:

$$P = \rho R \theta$$

, P - pressure, ρ - density, R - gas constant, θ - temperature

Motion equation:

$$\frac{\partial u}{\partial t} + u \frac{\partial u}{\partial x} = -\frac{1}{\rho} \frac{\partial P}{\partial x} - H$$

, u - air velocity, x - position

$H = \frac{\lambda}{2D} |u| u$ - pressure los

$$\lambda = \begin{cases} \frac{64}{Re} & \text{if } Re \leq 2300 \\ 0{,}3164\, Re^{-0{,}25} & \text{if } Re > 2300 \end{cases}$$

Continuity equation:

$$\frac{\partial \rho}{\partial t} + \rho \frac{\partial u}{\partial x} + u \frac{\partial \rho}{\partial u} = 0$$

1st Law of thermodynamics:

$$\frac{\partial \theta}{\partial t} = \frac{4h(\theta_a - \theta)}{\rho C_v D} - u \frac{\partial \theta}{\partial x} - \frac{R\theta}{C_v} \frac{\partial u}{\partial x} + \frac{1}{C_v} \frac{\lambda |u| u^2}{2D}$$

h - heat transf. coefficient, θ_a - atmosphere pressure

D - diameter of pipelines, λ - coefficient of pipeline friction

$$T = \frac{4h(\theta - \theta_a)}{\rho C_v D}$$

Heat transfer beetwen pipe and air.

$$h = 0.046\, R_e^{0.8} P_r^{0.4} \frac{k}{D}$$

P_r - Prandtl number

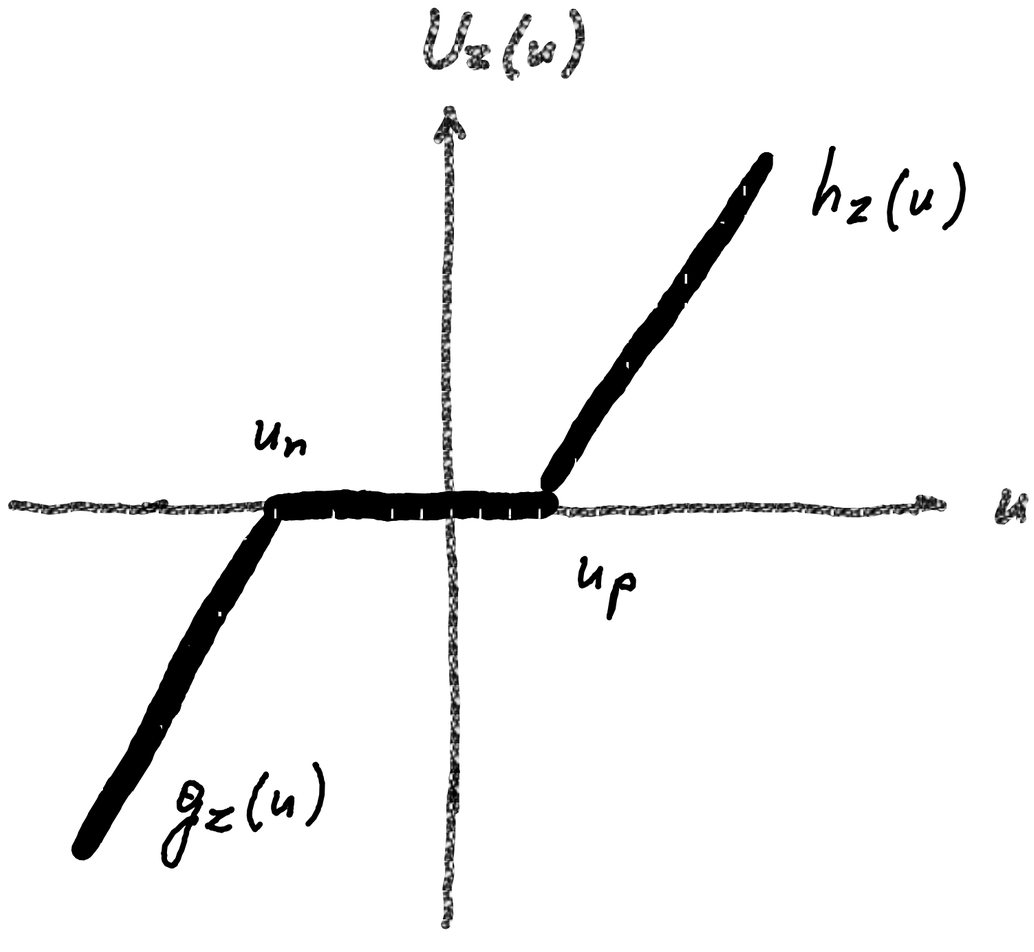
$k = 7{,}95 \cdot 10^{-5} \theta + 2.0465 \cdot 10^{-3}$

Thermal konduktivity

$|u|$?

Valve Deadzone :

$$U_z(u) = \begin{cases} g_z(u) < 0 & u \leq u_n \\ 0 & u_n < u < u_p \\ h_z(u) > 0 & u \geq u_p \end{cases}$$



Valve spool dynamic

Mechanic system

$$\ddot{x} = \frac{1}{m}\left(S_A p_A - S_B p_B - S_0 p_0 - F_f \right)$$

where

$$F_f = \begin{cases} C \cdot \dot{x} + \left[f_c + (f_s - f_c) e^{\left[-(\dot{x}/v_s)^s \right]} \right] \operatorname{sign}(\dot{x}) & \text{if } \dot{x} \le v_e \\ \mu \cdot \dot{x} & \text{if } \dot{x} > v_e \end{cases}$$

where C - viscous friction coeficient

f_c - Coloumb friction

f_s - maximum static friction

v_s - Stribeck velocity (0,1 - 0,0001 m/s)

s - arbitrary index (0,5 - 2)

v_e - critical velocity.

μ - dynamic friction factor.