THERMOFLUIDSTREAM COMMUNITY EVENT PUMPS

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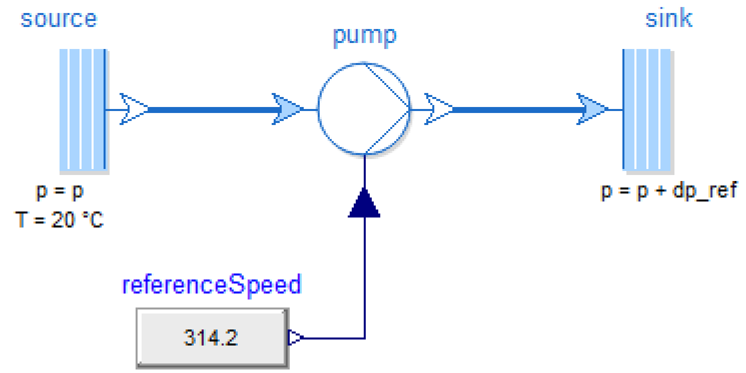
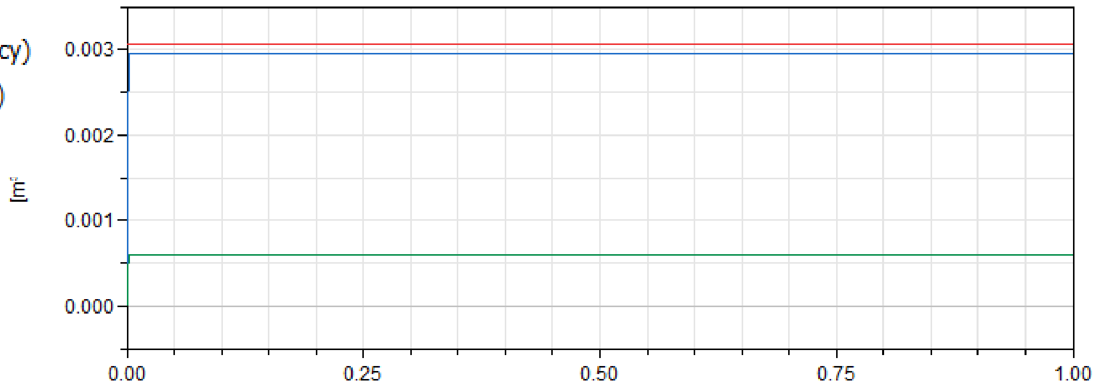
Motivation – Faulty Pump Model

- At *design angular velocity* and *design head* the volume flow rate was not the *design volume flow rate*

Scaling

TDH_D	3.6610	m	Design pressure head (max efficiency)
V_flow_D	3.06e-3	m³/s	Design volume flow (max efficiency)
omega_D	314.2	rad/s	Design angular velocity






```
Re_mod     := (omega_hat*r^2)/(mu_in)*(omega_s^1.5*f_q^0.75);
```

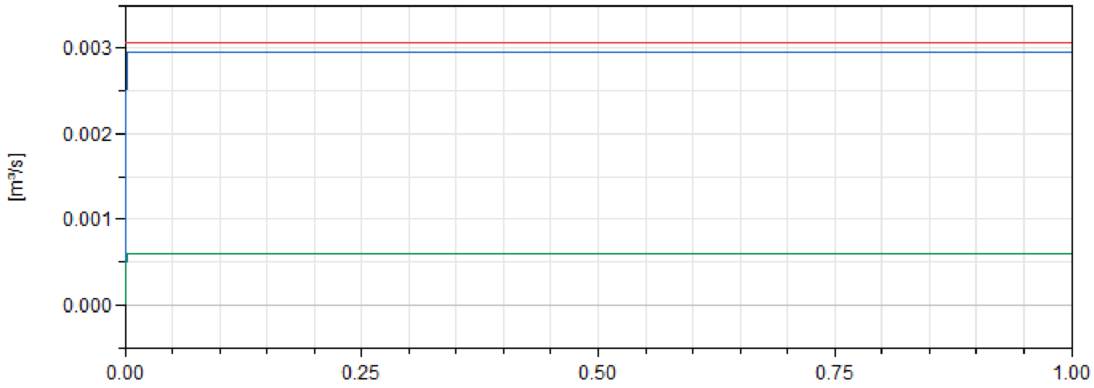
```
SI.SpecificVolume mu_in = Medium.dynamicViscosity(state_in) "Specific volume at inlet";
```

- Reynolds number (missing density) → fixed 90% of the error but…

Motivation – Too complicated

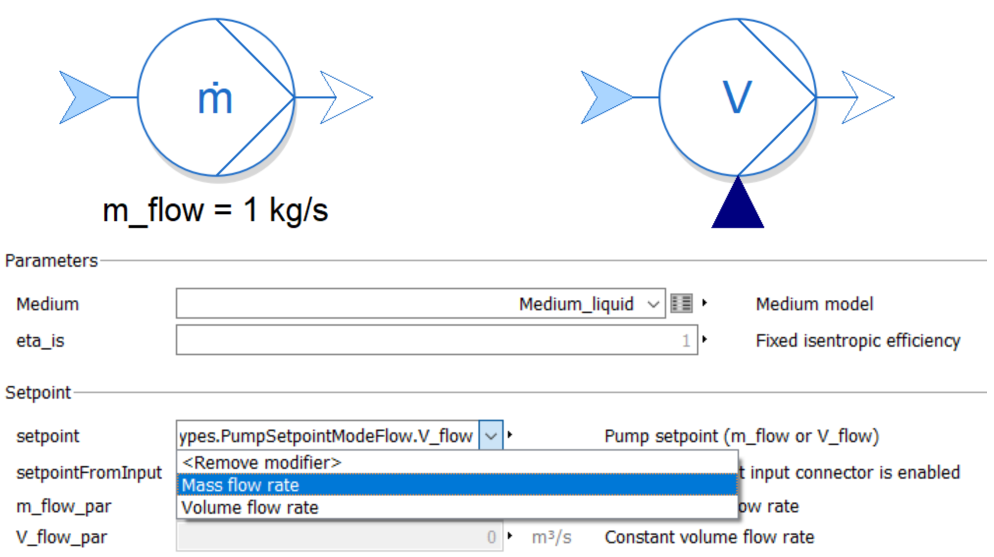
- Approach to extrapolate measurements data (water) to high viscosity fluids like oil not suitable for water itself since scaling factors are not equal to 1 for the reference fluid (water) → still 5% error
- Implementation as a function → hard to debug

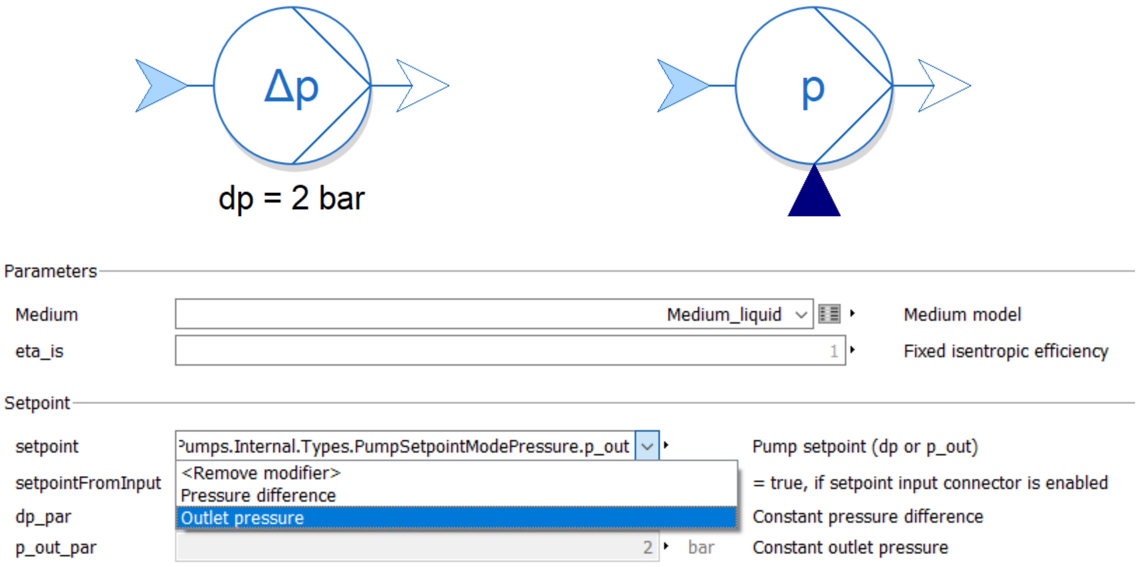
→ Decision to design new pump models



SimplePump

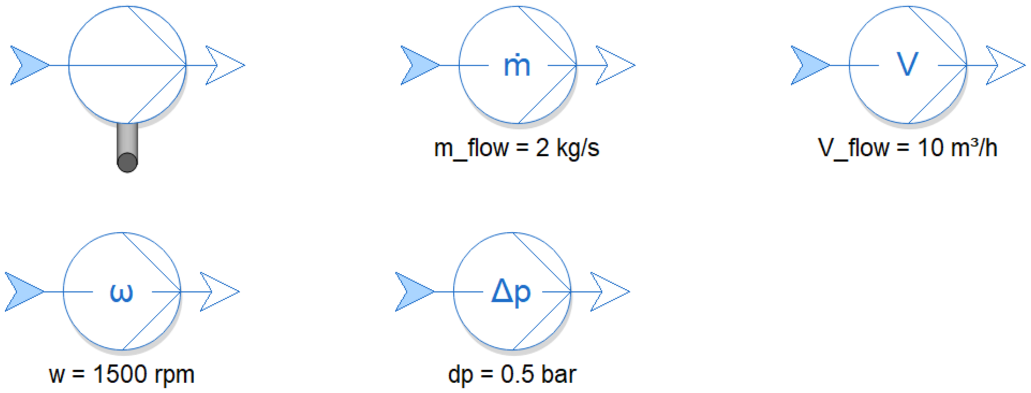
- Ideally controlled
  - Mass flow rate $\dot{m}$ or volume flow rate $\dot{V}$ – *FlowControlledSimplePump*
  - Pressure difference Δp or outlet pressure p_{out} – *PressureControlledSimplePump*
- Setpoint as paramater or input signal





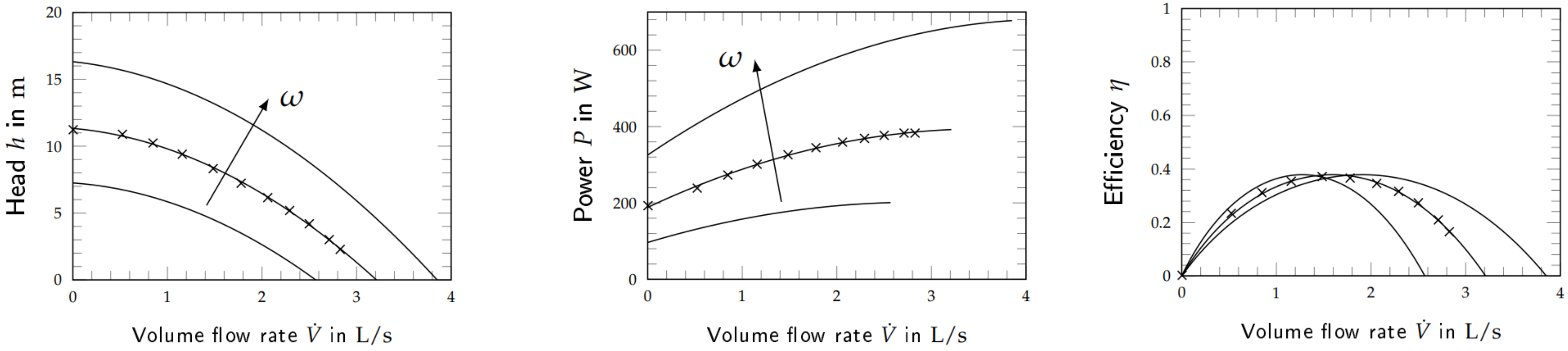
CentrifugalPump

- Ideally controlled
  - Mass flow rate $\dot{m}$ or volume flow rate $\dot{V}$ – Fl*owControlledCentrifugalPump*
  - Pressure difference Δp or outlet pressure p_{out} – *PressureControlledCentrifugalPump*
  - Angular velocity ω – *SpeedControlledCentrifugalPump*
- Or mechanical flange connector – *CentrifugalPump*



CentrifugalPump

- Approximation of head and power with quadratic polynomial
- Similarity laws for arbitrary speeds ($\dot{V} \sim \omega$, $h \sim \omega^2$, $P \sim \rho\omega^3$)
- 6 Coefficients → *BasedOnMeasurements* or *BasedOnCoefficients*

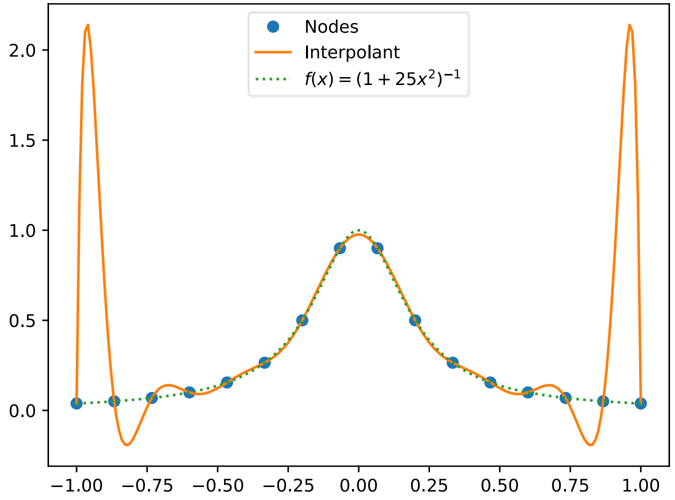


$$h = \left(c_1 \left(\frac{\omega}{\omega_{\text{ref}}} \right)^2 + c_2 \frac{\omega}{\omega_{\text{ref}}} \dot{V} + c_3 \dot{V}^2 \right)$$

$$P = c_1 \left(\frac{\omega}{\omega_{\text{ref}}} \right)^3 + c_2 \left(\frac{\omega}{\omega_{\text{ref}}} \right)^2 \dot{V} + c_3 \frac{\omega}{\omega_{\text{ref}}} \dot{V}^2$$

Comparison to Modelica.Fluid

- Approximation instead of Interpolation (no Oscillation, *Runge phenomena*)
- No function call (works fine for $\omega = 0$)



Modelica.Fluid

$$h = \left(\frac{\omega}{\omega_{\text{ref}}}\right)^2 \underbrace{\left(c_1 + c_2 \frac{\dot{V}}{\omega/\omega_{\text{ref}}} + \ldots + c_n \left(\frac{\dot{V}}{\omega/\omega_{\text{ref}}}\right)^{n-1}\right)}_{f_{\text{poly}}\left(\frac{\dot{V}}{\omega/\omega_{\text{ref}}}\right)}$$

$$P = \left(\frac{\omega}{\omega_{\text{ref}}}\right)^3 \underbrace{\left(c_1 + c_2 \frac{\dot{V}}{\omega/\omega_{\text{ref}}} + c_3 \left(\frac{\dot{V}}{\omega/\omega_{\text{ref}}}\right)^{2}\right)}_{f_{\text{quad}}\left(\frac{\dot{V}}{\omega/\omega_{\text{ref}}}\right)}$$

ThermofluidStream

$$h = \left(c_1 \left(\frac{\omega}{\omega_{\text{ref}}}\right)^2 + c_2 \frac{\omega}{\omega_{\text{ref}}} \dot{V} + c_3 \dot{V}^2\right)$$

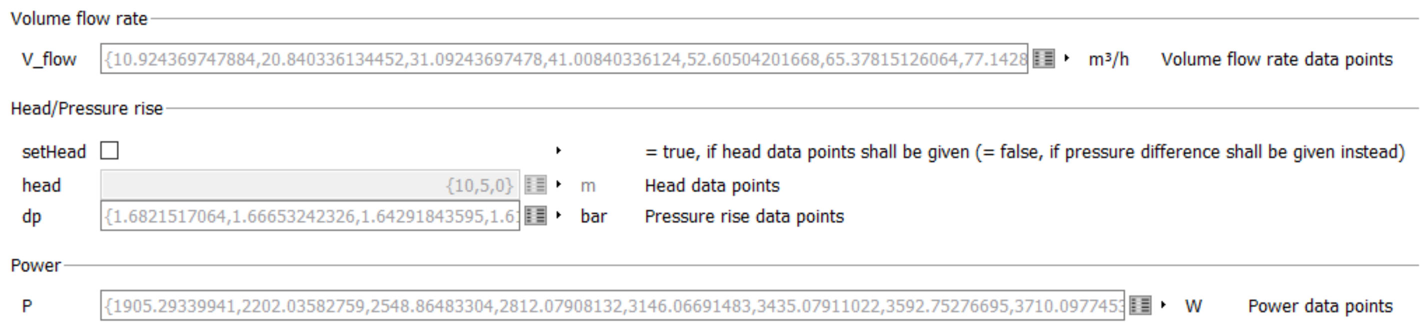
$$P = c_1 \left(\frac{\omega}{\omega_{\text{ref}}}\right)^3 + c_2 \left(\frac{\omega}{\omega_{\text{ref}}}\right)^2 \dot{V} + c_3 \frac{\omega}{\omega_{\text{ref}}} \dot{V}^2$$

CentrifugalPump BasedOnMeasurements

Parameterized by 3 vectors of measurement data of:

- Volume flow rate $\{\dot{V}_1, \ldots, \dot{V}_n\}$
- Head/pressure difference $\{h_1, \ldots, h_n\}$
- Power $\{P_1, \ldots, P_n\}$

at reference speed ω_{ref} and reference density ϱ_{ref}



CentrifugalPump BasedOnCoefficients

Parameterized by

1. Head at zero volume flow rate

$$h_{\mathrm{ref}} = h(\dot{V} = 0, \omega = \omega_{\mathrm{ref}})$$

2. Volume flow rate at zero head

$$\dot{V}_{\mathrm{ref}} = \dot{V}(h = 0, \omega = \omega_{\mathrm{ref}})$$

3. Initial slope of head curve

$$c_{2,\mathrm{head}} \approx 0.23 \pm 0.3$$

4. Max Efficiency $\eta_{\mathrm{ref}} = \max \eta$

5. Volume flow rate at max efficiency

$$\dot{V}/\dot{V}_{\mathrm{ref}}(\max \eta) \approx 0.515 \pm 0.023$$

6. Curvature of power curve

$$c_{3,\mathrm{power}} \approx -0.28 \pm 0.09$$