

Pump @model

The most general **Pump model** is given as a function of the **mass flowrate** on the intake p_{in} and discharge pressure p_{out} :

$$(1) \quad \dot{m} = M(p_{out}, p_{in})$$

It's often presented in terms of intake **volumetric flowrate**:

$$(2) \quad q = q_{in} = \frac{\dot{m}}{\rho(p_{in})} = \frac{M(p_{out}, p_{in})}{\rho(p_{in})}$$

where

$\rho(p)$ fluid density as a function of fluid pressure p

The electrical power consumption $W = \frac{dE}{dt}$ is given by:

$$(3) \quad W = \eta(q) \cdot q \cdot (p_{out} - p_{in})$$

where

η pump efficiency

In most practical cases the **pump model** (2) depends on the difference between intake and discharge pressure $p_{out} - p_{in}$ and called **Pump Characteristic Curve** (see **Fig. 1**):

$$(4) \quad q = q(p_{out} - p_{in})$$

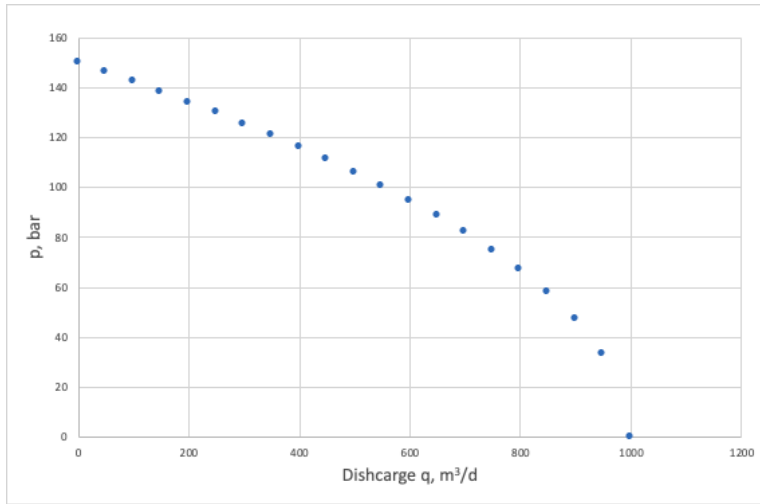


Fig. 1. Example of **Pump Characteristic Curve**.

A popular **pump** proxy model is given by the quadratic equation with 3 inputs ($\{q_{rfmax}, \delta p_{max}, k_f\}$):

$$(5) \quad q = \frac{q_{max}}{2 \cdot k_f} \cdot \left[-1 + k_f + \sqrt{(1 + k_f)^2 - 4 \cdot k_f \cdot (p_{out} - p_{in}) / \delta p_{max}} \right]$$

$$(6) \quad p_{out} = p_{in} + \delta p_{max} \cdot \left[1 + (k_f - 1) \cdot \frac{q}{q_{max}} - k_f \cdot \left(\frac{q}{q_{max}} \right)^2 \right]$$

$$(7) \quad \eta(q) = 4 \eta_{max} \cdot q / q_{max} \cdot (1 - q / q_{max})$$

where

$\delta p_{\max}$	maximum pressure gain that pump can exert over the input pressure p_{in}
$q_{\max}$	maximum flowrate that pump can produce
$k_f \in [0, 1]$	total hydraulic pump friction (dimensionless)
η	pump efficiency
$\eta_{\max}$	maximum pump efficiency

Real pumps have non-constant $k_f = k_f(q)$ friction coefficient which often modelled as a 3rd order polynomial and the overall real-pump model taking 6-inputs.

Many pumps can be normally adjusted by the variation of the working frequency which affects the maximum [pump flow rate](#) and maximum pressure gain as:

$$(8) \quad q_{\max} = q_{\max}^* \cdot \frac{f}{f^*}$$

$$(9) \quad \delta p_{\max} = \delta p_{\max}^* \cdot \left(\frac{f}{f^*}\right)^2$$

where

$q_{\max}$	maximum intake flowrate at the working frequency f	$\delta p_{\max}$	maximum pressure gain at the working frequency f	f	adjusted working frequency
$q_{\max}^*$	maximum intake flowrate at the nominal frequency f^*	$\delta p_{\max}^*$	maximum pressure gain at the nominal frequency f^*	f^*	nominal frequency

See also

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[Physics](#) / [Fluid Dynamics](#) / [Pipe Flow Dynamics](#) / [Pipe Flow Simulation \(PFS\)](#)

References