Pump control

Aim of the work

To understand the components of the process.

1 Pump

With ARMSTRONG 4380 water pump the system pressure is kept 80 kPa where water consumption varies between (10..50) L/s. [Curved arrow in the figure is not included into the task].

Pump speed $n = (0 - 1500)\ r/min$ controlled by a linear frequency converter with control signal $u = 0$ ...100%.

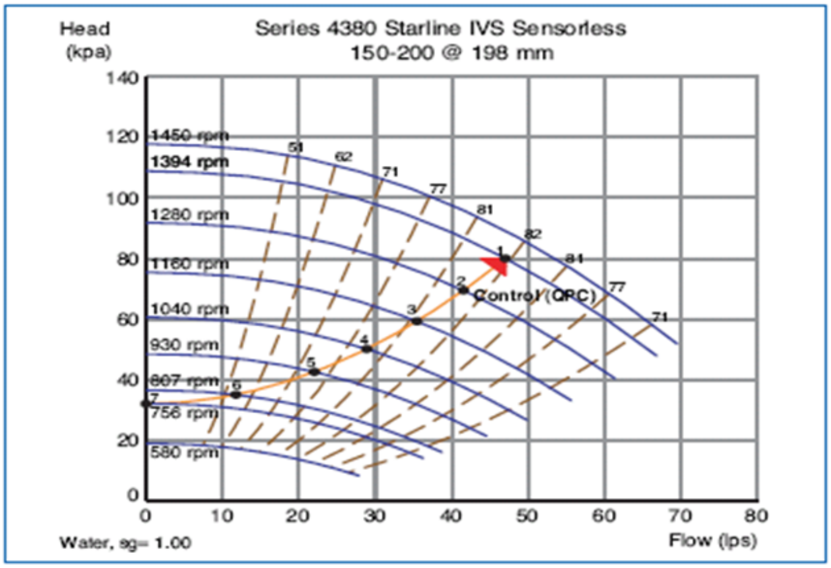


Figure 1: ARMSTRONG 4380 water pump

Work flow

1. Calculate coefficients k_1 and k_2 from the equation $p(q, n) = k_1 \cdot n^2 - k_2 \cdot q^2$ with rotation speed $n = 1450\ r/min$.

2. Do these parameters describe other pump speeds?

   (a) Calculate in Excel the pump equation $p(q, n)$ values as a function of $q = 0, 10, 20, \ldots, 80\ l/s$ (Line), with the parameters $n = 1450, 1394, \ldots$ (Column)

(b) Provide data by figure;

Place one on the other: task's and Excel figures,

Assess the match,

Adjust the parameters k_1, k_2.

3. Pressure p control $p = p_0$ by rotation speed n due to consumption q changes.

   (a) Determine the control signal u range.$n = F_1(p_0, q)$, n-range $n_{\max} \dots n_{\min}$,

   (b) What is the block (frequency converter + pump) gain K value and its range? Gain $K_p = \frac{\mathrm{d}p}{\mathrm{d}n}$.

Comments

2 Industrial pumps

Most liquids are moved by industrial pumps. Pumping costs consist of

- 5% of capital expenditures,
- $10 - 15\%$ of exploitation,
- 85% of the energy cost ($\approx 100\times$ more than the price!)

Industrial pumps use 20% of the power generated (paper, chemical and petrochemical industries, up to 30...50%).

Pumps with higher efficiency (with frequency converters) are $60 - 80\%$, this characteristic significantly affects the cost.

View:

http://www.PumpLearning.org,
http://www.pumps.org,
http://www.pumpsystemsmatter.org,
http://www.pump-zone.com,
http://www.engineeringtoolbox.com.

Where does the energy go during the pumping?

1. Potential energy

   - Pressurized liquid p, rises on the height h;
   - Work $E_p = mg \cdot h = V\rho gh = Vp$ $[J]$, where V - volume, p - pressure, q-consumption;
   - Power $P_p = \frac{\mathrm{d}E_p}{\mathrm{d}t} = qp$ $[W]$

2. Kinetic energy
   - Energy $E_k = mv^2/2$ $[J]$, where v - fluid velocity $[m/s]$;
   - Power $P_k = qv^2/2$ $[W]$ during the pumping *pot.energy* $\rightarrow$ *kin. energy*!
3. Losses (due to change in flow rate and direction) $\sim 10\%$.

3 Pump characteristics

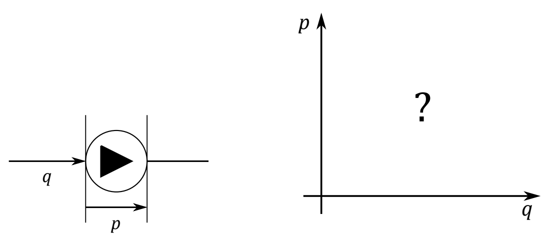


Figure 2: Pressure-consumption dependency

- Ideal pump $p = p_{\max}$

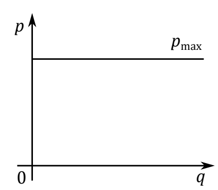


Figure 3: Ideal pump characteristic

- Fluid flow $\Delta p \sim q^2$, $\Delta p = k \cdot q^2$ turbulent

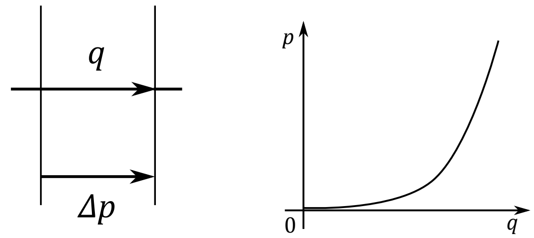


Figure 4: Turbulent flow

- Real pump—*centrifugal pump*; internal resistance: Opening S $[m^2]$ impeller

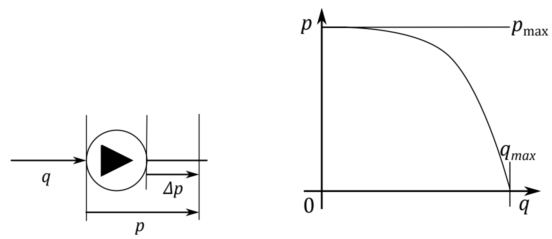
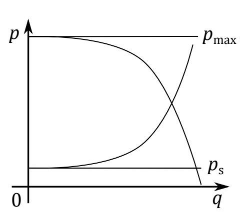


Figure 5: Centrifugal pump

  - $p = p_{\max} - \Delta p$; $F(p, q) = 0$; analogy with an electric battery, but nonlinear
  - maximum flow q_{max}
$$p = p_{\max}[1 - (q/q_{\max})^2]$$
  - Is it a maximum performance too? Pump curve $F(p, q) = 0$ is represented by two parameters.

- Real pump + external resistance (load)



Operating point (p, q), the pump characteristic is designated by the load and changes due to the load change.

- Variable rotational speed n, $p_{\max} \sim n^2$ parameters:

$$F(p, q, n) = 0, \quad p = k_1 \cdot n^2 - k_2 \cdot q^2 \qquad (k_1, k_2) \tag{1}$$

$$p = \ldots (n/n_o)^2 \qquad (\ldots n_o)$$

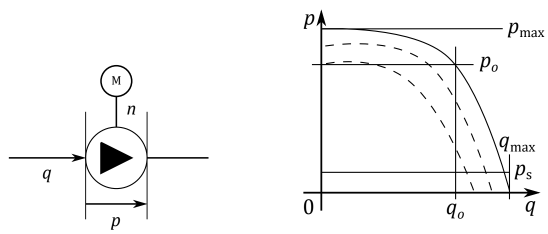


Figure 6: Variable rotational speed