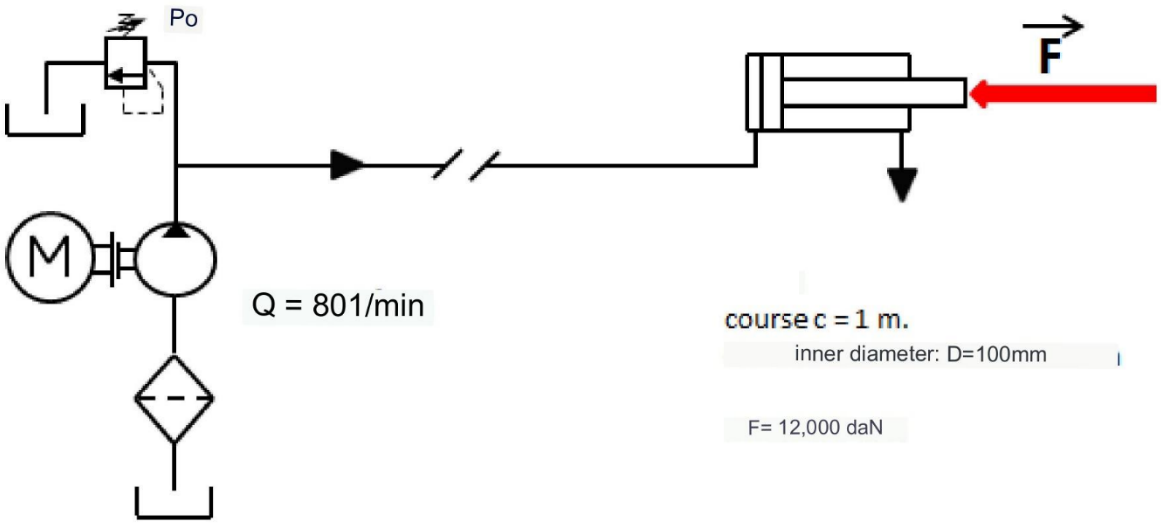
Industrial hydraulics

TD correction

1 Exercise 1 Calibration of the pressure relief valve of a pump supplying a cylinder



1.1 Required pressure in the cylinder

The pressure necessary in the cylinder to overcome the load of 12000daN is, taking into account the efficiency η of the jack, equal to:

$$P_{(Pa)} = \frac{F_{(N)}}{S_{(m^2)} \quad \eta} = \frac{120000}{\frac{\pi \quad 0.1^2}{4} \quad 0.9} = 170.10^5 \ Pa = 170 \ bars$$

1.2 Rod travel speed

The displacement speed of the cylinder rod is:

$$V_{(m/s)} = \frac{Q_{(m^3/s)}}{S_{(m^2)}} = \frac{\frac{80.10^{-3}}{60}}{\frac{\pi \quad 0.1^2}{4}} = 0.17 \ m/s$$

1.3 Rod exit time

The time t taken by the rod to cover the course c is:

$$t_{(s)} = \frac{c_{(m)}}{V_{(m/s)}} = \frac{1}{0.17} = 5.9 \ s$$

1.4 Pressure relief valve setting pressure

The pressure limiter setting pressure is given by the pressure required in the cylinder added to the pressure drop in the piping between the limiter and the cylinder.

Calculate the pressure drop in the piping. The inner diameter of the latter is given by $\Phi_{int} = \Phi_{ext} - 2e = 28 - 2 \times 3.2 = 21.6mm.$ The flow velocity of the fluid in the piping is then:

$$V_{(m/s)} = \frac{Q_{(m^3/s)}}{S_{(m^2)}} = \frac{\frac{80.10^{-3}}{60}}{\frac{\pi \quad 0.0216^2}{4}} = 3.64\ m/s$$

The flow regime prevailing in the pipe is given by the Reynolds number, i.e.:

$$Re = \frac{V_{(m/s)} \quad D_{(m)}}{\nu_{(myriastocke)}} = \frac{3.64 \times 0.0216}{34.10^{-6}} = 2312$$

Considering the flow regime as turbulent (Re> 2000) we can calculate the loss coefficient of charges as follows:

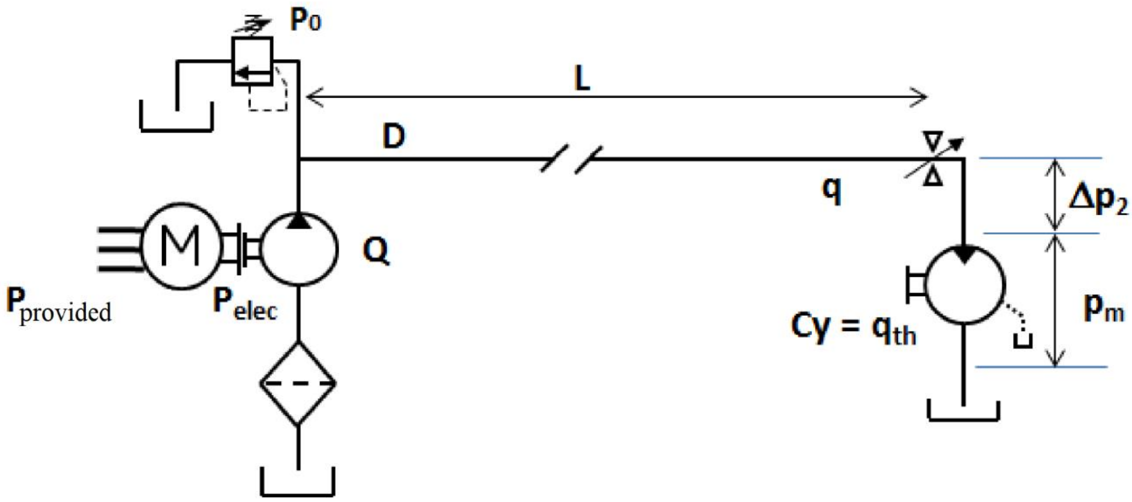
$$\lambda = 0.316\ Re^{-0.25} = 0.316 \times 2312^{-0.25} = 0.046$$

The pressure drop caused by the flow of oil in the piping is therefore:

$$\Delta_p = \lambda \frac{L_{(m)}}{D_{(m)}} \frac{\rho_{(kg/m^3)}\ V^2_{(m/s)}}{2} = 0.046 \frac{10}{0.0216} \frac{870 \times 3.64^2}{2} = 123000\ Pa = 1.23\ bar$$

The calibration of the pressure limiter is therefore adjusted to a pressure greater than or equal to Ptaring $= 170 + 1.23 =$ 171.23 bars. For example, we will take the Ptaring value of 175 bars.

2 Exercise 2: Hydraulic motor speed and torque



2.1 Hydraulic Motor Rotation Frequency

The rotational speed N of the hydraulic motor is:

$$N_{(tr/min)} = \frac{q_{(m^3/s)}\ \eta_{v,mot}}{q_{th_{(m^3)}}} = \frac{\frac{125.10^{-3}}{60} \times 0.9}{75.10^{-6}} = 1500\ tr/min$$

2.2 Hydraulic power required to operate the motor The

hydraulic power required to operate the motor is:

$$P_{hydro,mot} = q_{(m^3/s)}\ P_{m_{(Pa)}} = \frac{125.10^{-3}}{60} \times 140.10^5 = 29170\ W = 29,2\ kW$$

2.3 Torque on the output shaft of the hydraulic motor

By considering the system as perfect, we know that the hydraulic power at its input is entirely transformed into mechanical power. If the system has mechanical and hydraulic losses (expressed as efficiency) these apply to the input power to reduce it. We thus obtain the theoretical realization:

$$P_{hydro,mot}\ \eta_{v,mot}\ \eta_{m,mot} = P_{méca,mot} \Leftrightarrow q_{(m^3/s)}\ P_{m_{(Pa)}}\ \eta_{v,mot}\ \eta_{m,mot} = C_{(Nm)}\ \omega_{(rad/s)}$$

$$\Leftrightarrow C = \frac{q\ P_m\ \eta_{v,mot}\ \eta_{m,mot}}{\omega} = \frac{q\ P_m\ \eta_{v,mot}\ \eta_{m,mot}}{2\pi \frac{N}{60}}$$

But we know that:

$$q_{(m^3/s)} = \frac{q_{th_{(m^3)}}}{\eta_{v,mot}} \frac{N_{(tr/min)}}{60}$$

we then arrive at the relation:

$$C = \frac{\frac{q_{th_{(m^3)}}}{\eta_{v,mot}} \frac{N}{60}\ P_m\ \eta_{v,mot}\ \eta_{m,mot}}{2\pi \frac{N}{60}} = \frac{q_{th}\ P_m\ \eta_{m,mot}}{2\pi} = \frac{75.10^{-6} \times 140.10^5 \times 0.9}{2\pi} = 150.5\ Nm$$

2.4 Mechanical power on hydraulic motor output shaft

The mechanical power of the hydraulic motor is:

$$P_{méca,mot_{(W)}} = C_{(Nm)}\ \omega_{rad/s} = C\ 2\pi \frac{N}{60} = 150.5 \times 2\pi \frac{1500}{60} = 23628\ W = 23,6\ kW$$

We find the relation given at the beginning of question 3 between the hydraulic power at the input of the motor and the mechanical output power:

$$P_{hydro,mot}\ \eta_{v,mot}\ \eta_{m,mot} = P_{méca,mot} \Leftrightarrow 29.2\ kW \times 0.9 \times 0.9 = 23.65\ kW$$

2.5 Efficiency of the hydraulic pump

The output power of the electric motor (Pelec) being equal to the mechanical input power of the hydraulic pump, the overall efficiency of the latter is given by:

$$\eta_{pompe} = \frac{P_{hydro,pompe}}{P_{méca,pompe}} = \frac{Q_{(m^3/s)}\ P_{0_{(Pa)}}}{P_{elec_{(W)}}} = \frac{\frac{130.10^{-3}}{60} \times 145.10^5}{34150} = 0.92$$

2.6 General performance of the installation

The general efficiency of the installation is the ratio between the power available on the output shaft of the hydraulic pump and the electric power supplied to the electric motor. So we get

$$\eta_t = \frac{P_{méca,mot}}{\frac{P_{elec}}{\eta_{elec}}} = \frac{23.64}{\frac{34.15}{0.85}} = 0.59$$

2.7 Pressure drop in the piping

Let us first determine the flow regime. The inside diameter of the pipe is given by Pint $\Phi_{ext} - 2e = 33.7 - 2 \times 3.2 = 27.3\ mm.$ The flow velocity of the fluid in the piping is then:

$$V_{(m/s)} = \frac{q_{(m^3/s)}}{S_{(m^2)}} = \frac{\frac{125.10^{-3}}{60}}{\frac{\pi\ \ 0.0273^2}{4}} = 3.56\ m/s$$

2.3 Torque on the output shaft of the hydraulic motor

By considering the system as perfect, we know that the hydraulic power at its input is entirely transformed into mechanical power. If the system has mechanical and hydraulic losses (expressed as efficiency) these apply to the input power to reduce it. We thus obtain the theoretical realization:

$$P_{hydro,mot}\ \eta_{v,mot}\ \eta_{m,mot} = P_{méca,mot} \Leftrightarrow q_{(m^3/s)}\ P_{m_{(Pa)}}\ \eta_{v,mot}\ \eta_{m,mot} = C_{(Nm)}\ \omega_{(rad/s)}$$

$$\Leftrightarrow C = \frac{q\ P_m\ \eta_{v,mot}\ \eta_{m,mot}}{\omega} = \frac{q\ P_m\ \eta_{v,mot}\ \eta_{m,mot}}{2\pi \frac{N}{60}}$$

But we know that:

$$q_{(m^3/s)} = \frac{q_{th_{(m^3)}}}{\eta_{v,mot}} \frac{N_{(tr/min)}}{60}$$

we then arrive at the relation:

$$C = \frac{\frac{q_{th_{(m^3)}}}{\eta_{v,mot}} \frac{N}{60} P_m\ \eta_{v,mot}\ \eta_{m,mot}}{2\pi \frac{N}{60}} = \frac{q_{th}\ P_m\ \eta_{m,mot}}{2\pi} = \frac{75.10^{-6} \times 140.10^5 \times 0.9}{2\pi} = 150.5\ Nm$$

2.4 Mechanical power on the output shaft of the hydraulic motor

The mechanical power of the hydraulic motor is:

$$P_{méca,mot_{(W)}} = C_{(Nm)}\ \omega_{rad/s} = C\ 2\pi \frac{N}{60} = 150.5 \times 2\pi \frac{1500}{60} = 23628\ W = 23,6\ kW$$

We find the relationship given at the beginning of question 3 between the hydraulic power at the motor input and the mechanical power at the output:

$$P_{hydro,mot}\ \eta_{v,mot}\ \eta_{m,mot} = P_{méca,mot} \Leftrightarrow 29.2\ kW \times 0.9 \times 0.9 = 23.65\ kW$$