Power and Motion Control Systems - Practical Hydraulic Formulae

Geometric flow rate (pumps and motors)

How to calculate the geometric flow rate of a hydraulic pump/motor when pump or motor the shaft speed and geometric displacement are known (input values shown in yellow boxes).

A manufactures hydraulic gear pump has the following displacement and rotation speed.

Geometric displacement volume per revolution: $V_g := 23\ \text{cm}^3\ \text{rev}^{-1}$

Shaft rotation speed of pump/motor: $n := 1900\ \text{rev min}^{-1}$

Volumetric efficiency of pump/motor: $\eta_{vol} := 95\ \%$

Geometric flow rate (without SMath units): $Q_v := \dfrac{23 \cdot 1900 \cdot 0.95}{1000} = 41.515$

Geometric flow rate (using SMath units): $Q_v := V_g \cdot n \cdot \eta_{vol} = 41.515\ \text{L min}^{-1}$

If the system pressure is known then the theoretical shaft torque can be calculated for the specified pump.

Differential system pressure: $\Delta p := 200\ \text{bar}$

Mechanical hydraulic efficiency: $\eta_{mh} := 95\ \%$

Theoretical shaft torque (without SMath units): $T := \dfrac{23 \cdot 200 \cdot 0.95}{20 \cdot \pi} = 69.5507$

Theoretical shaft torque (using SMath units): $T := V_g \cdot \Delta p \cdot \eta_{mh} = 69.5507\ \text{N m}$

Since the shaft speed and torque are known the shaft power can be estimated.

Shaft power (without SMath units): $P := \dfrac{69.5507 \cdot 1900 \cdot 0.95}{9550} = 13.1454$

Shaft power (using SMath units): $P := T \cdot n \cdot \eta_{mh} = 13.1464\ \text{kW}$

The hydraulic power can also be calculated as the flow rate and pressure are known.

Hydaulic power (without SMath units): $P_{hyd} := \dfrac{41.515 \cdot 200 \cdot 0.95}{600} = 13.1464$

Hydaulic power (using SMath units: $P_{hyd} := Q_v \cdot \Delta p \cdot \eta_{mh} = 13.1464\ \text{kW}$

This can also be converted into heat equivalent: $P_{hyd1} := \dfrac{41.515 \cdot 200 \cdot 0.95}{10} = 788.785$

$P_{hyd} = 788.785\ \text{kJ min}^{-1}$

Power and Motion Control Systems - Practical Hydraulic Formulae (cylinders)

Geometric flow rate for hydraulic cylinders if the piston speed is known

Hydraulic cylinder piston diameter: $d_1 := 160\ mm$

Hydraulic cylinder piston rod diameter: $d_2 := 90\ mm$

Piston stroke speed required: $v := 23\ m\ min^{-1}$

Full bore area of hydraulic cylinder (without SMath units): $A_{fb} := \frac{\pi \cdot 160^2 \cdot 0.01}{4} = 201.062$

Full bore area of hydraulic cylinder (using SMath units): $A_{fb} := \frac{\pi \cdot d_1^2}{4} = 201.062\ cm^2$

Rod area of hydraulic cylinder (without SMath units): $A_r := \frac{\pi \cdot 90^2 \cdot 0.01}{4} = 63.617$

Rod area of hydraulic cylinder (using SMath units): $A_r := \frac{d_2^2 \cdot \pi}{4} = 63.617\ cm^2$

Annular area of hydraulic cylinder (without SMath units): $A_{an} := 201.062 - 63.617 = 137.445$

Annular area of hydraulic cylinder (using SMath units): $A_{an} := A_{fb} - A_r = 137.445\ cm^2$

Full bore geometric flow rate required: (without SMath units) $Q_{fb} := \frac{201.0619 \cdot 23}{10} \cdot 0.95 = 439.32$

Full bore geometric flow rate required: (with SMath units) $Q_{fb} := A_{fb} \cdot v \cdot \eta_{vol} = 439.32\ L\ min^{-1}$

Annular geometric flow rate required (without SMath units): $Q_{an} := \frac{137.445 \cdot 23 \cdot 0.95}{10} = 300.317$

Annular geometric flow rate required (with SMath units) : $Q_{an} := A_{an} \cdot v \cdot \eta_{vol} = 300.317\ L\ min^{-1}$

Piston speed based on pump flow rate above (without SMath units): $v_1 := \frac{41.515 \cdot 0.95 \cdot 10}{201.062} = 1.962$

Piston speed based on pump flow rate above (with SMath units): $v_1 := \frac{Q_v \cdot \eta_{vol}}{A_{fb}} = 1.962\ m\ min^{-1}$

The theoretical force of the cylinder can now be estimated

Theoretical force on full bore of cylinder: (without SMath units) $F_{fb} := 201.0619 \cdot 200 \cdot 10 = 4.021 \cdot 10^5$

Theoretical force on full bore of cylinder: (with SMath units) $F_{fb} := A_{fb} \cdot \Delta p = 4.021 \cdot 10^5\ N$