LECTURE 7 TO 9 – HYDRAULIC PUMPS

SELF EVALUATION QUESTIONS AND ANSWERS

1. A gear pump has a 75mm outside diameter, a 50mm inside diameter, and a 25mm width. If the actual pump flow at 1800rpm and rated pressure is $0.106 m^3/min$, what is the volumetric efficiency?

2.A gear pump has a 75mm outside diameter, a 50mm inside diameter, and a 25mm width. If the volumetric efficiency is 90% at rated pressure, what is the corresponding actual flow-rate? The pump speed is 1000rpm.

3. A vane pump is to have a volumetric displacement of 5 cm^3. It has a rotor diameter of 2 cm, a cam ring diameter of 3 cm. What must be the eccentricity?

4. A vane pump has a rotor diameter of 50 mm, a cam ring diameter of 75mm, and a vane width of 50 mm. If the eccentricity is 8mm, determine the volumetric displacement.

5.A vane pump is to have a volumetric displacement of 82 cm3. It has a rotor diameter of 5 cm , a cam ring diameter of 7.5 cm , and a vane width of 4 cm. what must be the eccentricity?. What is the maximum volumetric displacement possible?

6 An axial piston pump has nine pistons arranged on a piston of circle 125 mm diameter. The diameter of the piston is 15mm. The cylinder block is set to an off set angle of 10 ° . If pump runs at 1000 RPM with an volumetric efficiency of 94 %. Find the flow rate in LPS.

7. A fixed displacement vane pump delivers 68.94 bar oil to an extending hydraulic cylinder at 0.00126$\frac{m^3}{s}$When the cylinder is full extended, oil leaks past its piston at rate of 4.42x$10^{-5}\frac{m^3}{s}$ The pressure relief valve setting is 82.75 bar. If a pressure-compensated vane pump were used it would reduce the pump flow 0.0012$\frac{m^3}{s}$6 to 4.42x$10^{-5}\frac{m^3}{s}$when the cylinder is fully extended to provide the leakage flow at the pressure relief valve setting of 82.75 bar. How much hydraulic horse power would be saved by using the pressure compensated pump?

8.Find the offset angle for an axial piston pump that delivers 0.001$\frac{m^3}{s}$ at 1000rpm .The pump has 9 pistons and each piston has 24.2 mm diameter and arranged on a 127mm diameter pitch circle. The volumetric efficiency is 90 %

9.A pump has displacement volume of 100 cm^3. It delivers 0.0015m^3/sec at 1000rpm and 70bar.If the prime mover input torque is 120 N.m, calculate a) the overall efficiency of the pump b) theoretical torque required to operate the pump.

10. A hydraulic circuit consists of a fixed displacement gear pump supplying hydraulic fluid to cylinder which has a bore of 100 mm diameter, a rod of 56mm diameter and a stroke of 400mm. Pumps are available with displacement increasing in steps of 1 ml/rev from 5 ml. the volumetric efficiency is 88% and its overall efficiency is 80%. The pump is driven directly by an electric motor with an on load speed of 1430 RPM. Select a suitable pump so that the cylinder can be reciprocated through a complete once a every 12 seconds.

Q1 Solution:

Volume $V = \frac{\pi}{4}(D_o{}^2 - D_i{}^2)L$

$$= \frac{\pi}{4} \times (0.075^2 - 0.050^2) \times 0.025$$

$$= 0.0000614\, m^3/rev$$

Theoretical flow rate, $Q_T \;=\; V_D N = 0.0000614x1800 = 0.115\ \text{m}^3\ /\text{min}$

The volumetric efficiency, $\eta_v \;=\; \frac{Q_A}{Q_T}$

$$= \frac{0.106}{0.115} = \;0.921 \;=\; 92.1\%$$

Q2 Solution:

Volume $= \frac{\pi}{4}(D_o{}^2 - D_i{}^2)L$

$$= \frac{\pi}{4} \times (0.075^2 - 0.05^2) \times 0.025 = \;0.0000614\ \text{m3/rev}$$

$$V_D = \;0.0614\ \text{L}$$

Actual flow-rate , $Q_A = \eta_v \times Q_T$

$$= \;0.90 \times 0.0000614 \times 1000 \;=\; 0.0553\ \text{m3 /min}$$

$$Q_A = 55.3\ Lpm$$

Q3Solution Eccentricity, $e = \frac{2V_D}{\pi(D_L+D_R)L} = \frac{2\times 5}{\pi(2+3)\times 2} = \;0.318\ \text{cm}$

Q4 Solution

Volumetric displacement, $V_D = \frac{\pi}{4}(D_c + D_R) \times (2e)L$

$$= \frac{\pi}{4} \times (0.05 + 0.075) \times (2 \times 0.008) \times 0.05$$

$$= 0.0000785 \text{ m}^3$$

Q5 Solution

$V_D = volumetric\ displacement = 82\ cm^3 = 82 \times 10^{-6} m^3$
$D_R = diameter\ of\ rotor = 5cm = 0.05m$
$D_C = diameter\ of\ cam\ ring = 7.5cm = 0.075m$
width of vane $= 4\text{cm} = 0.04\text{m}$

a) Eccentricity

Volumetric displacement, $V_D = \frac{\pi}{4}(D_c + D_R) \times (2e)L$

$$e = \frac{V_D}{\frac{\pi}{4}(D_c + D_R) \times L}(2) = \frac{82 \times 10^{-6} m^3}{\frac{\pi}{4}(0.075 + 0.05) \times 0.04}(2) = 0.01044 = 10.44\ mm$$

b) Maximum possible displacement $V_{D(max)}$

$volumeteric\ displacement\ is\ \text{max}\ at\ e = e_{max}$

$$\text{e}_{\text{max}} = \frac{D_c - D_R}{2} = \frac{0.075 - 0.05}{2} = 0.0125\text{m} = 12.5\text{mm}$$

Volumetric displacement, $V_{D(max)} = \frac{\pi}{4}(D_c + D_R) \times (2\text{e}_{\text{max}})L$

$$V_{D(max)} = \frac{\pi}{4}(0.075 + 0.05) \times (2x0.0125)0.04 = 9.818 \times 10^{-6} m^3 = 98.18\ cm^3$$

Q6Solution

Theoretical discharge of axial piston pump

$$Q_{T=}\ \text{DANY}\ \tan(\theta)$$

$$= 0.125 \times \frac{\pi}{4} \times 0.015^2 \times 9 \times \tan(10) \times 1000$$

$$= 0.03506 \frac{m^3}{\text{min}} = \frac{0.03506}{60} = 5.8433x10^{-4} \frac{m^3}{\text{sec}}$$

Actual discharge, $Q_A = Q_T \times \eta_{vol}$

$$= 5.8433x10^{-4}\text{x}\ 0.94 = 5.493x10^{-4} \frac{m^3}{\text{sec}}$$

1L =1000cc = 1000 $\text{x}10^{-6} m^3 = 1000 m^3$

$5.493 m^3 = \frac{5.493x10^{-4}}{1000}$=0.5493 L

Thus actual discharge = $0.5493 \frac{L}{\text{sec}} \cong 0.55$ LPS

Q7 Solution

The fixed displacement vane pump produces $0.00126\frac{m^3}{s}$ at 82.75 bar when the cylinder is fully extended ($4.42x10^{-5}\frac{m^3}{s}$ leakage flow through the cylinder and $0.001216\frac{m^3}{s}$ through the relief valve).Thus, we have

Hydraulic HP lost = $pQ = 82.75 \times 10^5 \times 0.00126 \cong 10427 \text{ watts} = 10.427\text{kW}$

A pressure-compensated pump would produce only $4.42\times 10^{-5}\frac{m^3}{s}$at when the cylinder is fully extended. For this case have

Hydraulic HP lost = $pQ = 82.75 \times 10^5 4.42 \times 10^{-5} \cong 367 \text{ Watts} = 0.367 \text{ kW}$

Hence, the hydraulic power saved = 10427 – 367 = 10060 Watts=10.060 kW. This power saving occurs only while the cylinder is fully extended.

Q8 Solution

:$Q_A = Q_T \times \eta_{vol}$

Volumetric efficiency $\eta_{vol} = \frac{\text{actual discharge}}{\text{theoretical discharge}} = \frac{0.001\frac{m^3}{s}}{Q_T} \times 100$

$$0.90 = \frac{0.001\frac{m^3}{s}}{Q_T}$$

$$Q_T = \frac{0.001\frac{m^3}{s}}{0.90} = 0.00111\frac{m^3}{s}$$

Theoretical discharge of axial piston pump

$$Q_{T=} \text{DANY } \tan(\theta)$$

$$0.00111 = 0.127 \times \frac{\Pi}{4} \times 0.0242^2 \times 9 \times \tan(\theta) \times \frac{1000}{60}$$

Solving $\theta = 7.2°$

Q9 Solution

$V_D = 100\frac{cm^3}{rev} = 100 \times 10^{-6}\frac{m^3}{rev}$

$Q_A = 0.0015\ m3/sec$

$N = 100rpm$

$P = 70\ bar$

$T_A = 120Nm$

$$Theoretical\ discharge = V_D \times N = 100 \times 10^{-6} \times 1000 = 0.1\ \text{m}^3/min$$

$$\text{Q}_\text{T} = 1.667\text{X}10^{-3}\ \text{m}^3/\text{sec}$$

Volumetric efficiency,

$$\eta_v = \frac{Q_A}{\text{Q}_\text{T}} = \frac{0.0015}{1.667 \times 10^{-3}}$$

i.e. $\eta_v = 90\%$

Output power delivered by pump $= \text{P} \times \text{Q}_\text{T} = 7000 \times 1.667 \times 10^{-3} = 11.667\text{kW}$

Actual power given to pump $= 2 \times \pi \times 1000 \times 120/60 = 12.566\text{kW}$
Mechanical efficiency

$$\eta_m = \frac{12.566}{11.667} = 92.84\%$$

Overall Efficiency
$\eta_o = \eta_m \times \eta_v = 0.984 \times 0.9 = 0.83556 = 83.556\%$
Theoretical torque required to operate the pump
$T_T = T_A \times \eta_m = 120X0.9284\ Nm$
$T_T = 111.408\text{Nm}$
Note that the product $T_A \times N$ gives power in units of N.m/s (W), where torque (T_A) has units of N.m and shaft speed has units of rad/s .

Theoretical torque = Actual torque x Mechanical efficiency = 120 x 0.9284 = 111.4 Nm

Thus, due to mechanical losses within the pump, 120 Nm of torque are required to drive the pump instead of 111.4 Nm

Q10 Solution

$$\boldsymbol{extendtime} = \frac{\frac{\pi}{4}(\mathrm{D}^2\mathrm{L})}{\mathrm{Q}}$$

$$\boldsymbol{retracttime} = \frac{\frac{\pi}{4}(\mathrm{D}^2 - \mathrm{d}^2)\mathrm{L}}{\mathrm{Q}}$$

Cycle time = extend time + retract time

$$\frac{12}{60} = 0.2\ min = \frac{\frac{\pi}{4}(\mathrm{D}^2\mathrm{L})}{Q} + \frac{\frac{\pi}{4}(\mathrm{D}^2 - \mathrm{d}^2)\mathrm{L}}{Q}$$

$$\frac{12}{60} = 0.2\ min = \frac{\frac{\pi}{4}(0.1^2\mathrm{L})}{Q} + \frac{\frac{\pi}{4}(0.1^2 - 0.056^2)4}{Q}$$

Actual flow pump (Q) is obtained by solving above equation
Q = 0.0265 m^3/min

$$Theoreticalpumpflow = \frac{Actualflowofpump}{Volumetricefficiency} = \frac{Q}{\eta_V} = 0.030m^3\ /\text{min}$$

$$Theoreticalpumpflow = speedofpumpxpumpdisplacement = N_P x D_P$$

Pump displacement $D_P = \frac{0.030}{1430} = 2.1\ x10^{-5}\frac{\mathrm{m}^3}{\mathrm{rev}} = 21\ \text{ml/rev}$
A pump with 21 ml /rev displacement is to be selected.