LECTURE 24 TO 26 – ACCUMULATORS

SELF EVALUATION QUESTIONS AND ANSWERS

1. An accumulator has a ram diameter of 25 cm and lift 5 m. it is loaded with 50 Tonnes of total weight. The packing friction is 5% of the load on the ram. Find the power delivered to the main if the ram descends steadily through its full stroke in 200 seconds while the pump delivers 800 LPM though the accumulator

2 Calculate the accumulator volume of a bladder type accumulator having a gas ration of 3:1 at full charged condition. The index of polytropic expansion is 1.25. The system demand volume is 6 liter. The permissible drop is 5% (x = 0.05).

3. What size of accumulator is necessary to supply 10000 cm3 of fluid is a hydraulic system of maximum pressure of 200 bar to 100 bar minimum. Assuming N2 gas per-charged pressure of 80 bar. Find adiabatic and isothermal solution.

4. A gas charged accumulator supplies energy to a system with 10litres of oil within the pressure range of 200bar to 150 bar. The accumulator has the per-charge pressure of 90bar. What should be the size of the accumulator, if the oil is to be supplied i) in about 8 seconds and (ii) in about 8 minutes time?

5 The circuit has been designed to crush a car body into bale using a 150 mm diameter hydraulic cylinder. The hydraulic is to extend 2.50 m during a period of 10s. the time between crushing strokes is 8 min. the following accumulator gas absolute pressures are given:

P_1 = Gas precharge pressure 90bar(abs), P_2 = Gas charge pressure when pump is turned on 200 bar(abs) = pressure relief value setting,P_3 = Minimum pressure required to actuate load 125 bar (abs).Calculate: (i) the required size of the accumulator

(ii) What are the pump hydraulic kW power and the flow requirements with and without accumulator?

Q1 Solution:

Pressure of water during descent $= \frac{\text{Effective load}}{\text{Area of plunger}}$

P $= \frac{50\times1000\times0.95\times9.18}{\frac{\pi}{4}\times(0.25)^2}$ Pa

= 9492.76 kPa

Pressure head $= \frac{P}{\rho g}\,\text{m}$

= 967.66 m

work done by the accumulator due to pump work

= m × g × head N-m

$= \frac{800\times9.81}{60}\times 967.66\ \text{Watts}$

= 12650 watts

work done by the accumulator during its discharge

$= \frac{50\times10^3\times9.81\times0.95\times5}{200}\,\text{N}-\text{m/s}$

= 11637.5 watts

Total work added to the pipe line = Work supplied by the accumulator + Work supplied by the pump

= 138207.67 W

Therefore, power delivered to the pipe line = 138.208 kW

Q2 Solution:

$$\left(\frac{V_{HP}}{V_{HP}+6}\right) = (1-0.05)^{1/1.25} = 0.96$$

∴ V_{HP} = 0.96(V_{HP}+6) = 144 litres

∴ V_{Acc} = $144+\frac{144}{3}$ = **192 litres**

Q3 Solution:

V_1 = Volume of accumulator cm^3

V_2 = Volume of gas at high pressure, mc^3

P_2 = Maximum pressure, bar

P = Minimum pressure, bar

P_1 = Per-charged pressure, bar

V_1=? V_2 ? = P_1 = 80 bar, p_2 = 200 bar, P= 100 bar

Let V_1be the volume of gas occupied in the accumulator at per-charged 80 pressures.
Let V_2 be the volume of gas occupied in the accumulator at 200 bar and that time 10,000 cm^3 of oil has also occupied in the accumulator.

$$V_1 = V_2 + 10000 \text{ cm}^3$$

$$V_2 = V_1 - 10000$$

(a) Adiabatic process:

$$P_1 V_1^\gamma = P_2 V_2^\gamma$$

$$\gamma = 1.25$$

$$80 \times V_1^\gamma = 200 \times (V_1 - 10000)^\gamma$$

$$\frac{80}{200} = \left(\frac{V_1 - 10000}{V_1}\right)^\gamma$$

$$0.4 = \left(\frac{V_1 - 10000}{V_1}\right)^{1.25}$$

$$\frac{V_{1-10000}}{V_1} = (0.4)^{\frac{1}{1.25}}$$

$$\frac{V_{1-10000}}{V_1} = (0.4)^{08}$$

$$\frac{V_{1-10000}}{V_1} = 0.4804$$

$$V_1 - 10000 = 0.4804 V_1$$

$$V_1 - 0.4804 V_1 = 10000$$

$$0.5195 V_1 = 10000$$

$$V_1 = 19249.27 \text{ cm}^3$$

Size of accumulator = 19249.27 cm^3

(b) Isothermal precess:

$$P_1 V_1 = P_2 V_2$$

$$80 \times V_1 = 200 \times (V_1 - 10000)$$

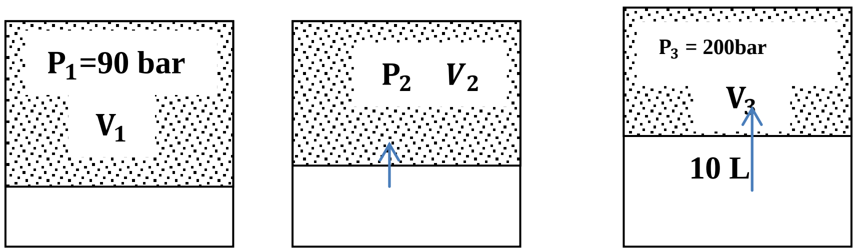
$$\frac{80}{200} = \frac{V_1 - 10000}{V_1}$$

$$0.4 = \frac{V_1 - 10000}{V_1}$$

$$V_1 - 10000 = 0.4V_1$$
$$V_1 - 0.4V_1 = 10000$$
$$0.6\,V_1 = 10000$$
$$V_1 = 16666.66\ cm^3$$
$$\text{Size of accumulator} = 16666.66\ cm^3$$

Q4 Solution:

Stages of precharging, charging and delivery is shown below



Let precharging pressure be P_1 (90 bar) and V_1 . Gas is compressed by incoming oil from pressure 90 to 200 bar and when the bladder is compressed to 200 bar the volume of oil inside the accumulator is 10 Liters. Therefore we can write.

V_3-V_1=10

Considering adiabatic condition with γ= 1.3

(i) In about 8 seconds:

$$P_1V_1^{\gamma} = P_2V_2^{\gamma}$$

$$90(V_1)^{\gamma} = 200 \times \left(V_1 - \frac{10}{8}\right)^{\gamma}$$

$$90(V_1)^{1.3} = 200 \times (V_1 - 1.34)^{1.3}$$

$$\frac{90}{200} = \left(\frac{V_1 - 1.25}{V_1}\right)^{1.3}$$

$$\left(\frac{V_1 - 1.34}{V_1}\right) = \left(\frac{90}{200}\right)^{1/1.3}$$

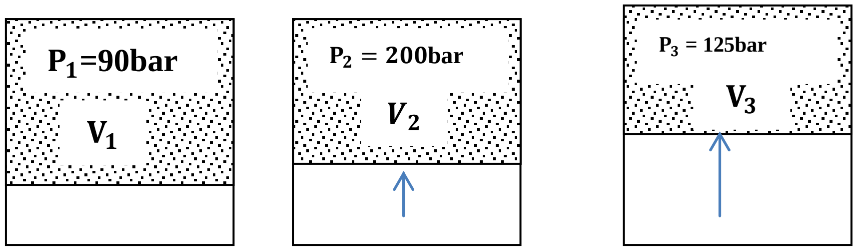
V_1=2.723 LPS

Capacity of accumulator =2.723×8 =21.78 Liters

(ii) In about 8 minutes:

Capacity of accumulator =2.723×8× 60 =1307.34 Liters

Q5Solution: Stages of precharging, charging and delivery is shown below



Let precharging pressure be P_1 (90 bar) and V_1 . Gas is compressed by incoming oil from pressure 90 to 200 bar and accumulator is discharged till pressure reaches 125bar.

Solution

Case a – Without the use of accumulator

Let compression and expansion of gas follows isothermal law

$$P_1 V_1 = P_2 V_2 = P_3 V_3$$

V_c=volume of hydraulic cylinder. It can accommodate (V_3 - V_2) amount of oil

$V_c = (V_3 - V_2)$

$P_3 V_3 = P_2 V_2$

$V_3 = \frac{P_2 V_2}{P_2} = \frac{200 \times V_2}{125} = 1.60\ V_2$---- (a)

$V_c = \frac{\pi}{4} d^2 I = \frac{\pi}{4}(0.150)^2 \times 2.50 = 0.0442\ m^3 = (V_3 - V_2)$---(b)

Using (a) in (b) and solving we get

$V_2 = 0.07362\ m^3$

$V_3 = 0.11780\ m^3$

$V_1 = \frac{P_2 V_2}{P_1} = \frac{200 \times 0.07362}{900} = 0.1636\ m^3 = 163.6\ \text{Litres}$

Case b – With the use of accumulator

Pump charges accumulator in every 2.5 minutes. In other words, 2 times in 5 minutes.

Flow supplied by the pump $Q_p = \frac{4(V_3 - V_2)}{30}$

$$Q_p = \frac{4(44.2)}{300} = 0.5893 \text{ LPS}$$

Neglecting all losses, Power supplied to pump

$$P_{pump} = P_2 \times Q_{pump}$$

$$= \frac{(200\times10^5)(0.5893\times10^{-3})}{1000} = 11.79 \text{ kW}$$

Without accumulator: Pump extends cylinder in 10 sec.

Flow supplied by the pump $Q_p = \frac{44.2}{10} = 4.42 \text{ LPS}$

Neglecting all losses, Power supplied to pump

$$P_{pump} = P_2 \times Q_{pump} = \frac{(125\times10^5)(441\times10^{-5})}{1000} = 55.25 \text{ kW}$$

It can be see that Flow and power requirement by pump is more without accumulator.