LNCT GROUP OF COLLEGES

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Topic: Hydraulic Press and

Hydraulic Accumulator

Hydraulic Press and Hydraulic Accumulator

Hydraulic Press

The hydraulic press is a device used for lifting heavy weights by the application of a much smaller force. It is based on Pascal's law, which states that the intensity of pressure in a static fluid is transmitted equally in all directions.

The hydraulic press consists of two cylinders of different diameters. One of the cylinder is of large diameter and contains a ram, while the other cylinder is of smaller diameter and contains a plunger as shown in fig. 1.The two cylinders are connected by a pipe. The cylinders and pipe contain a liquid through which pressure is transmitted.

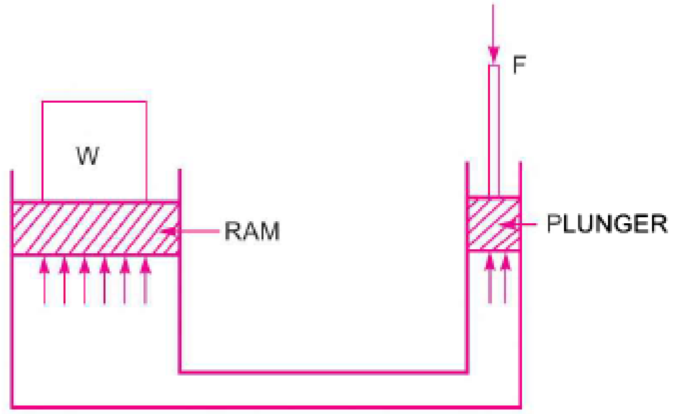

Fig.1 The hydraulic press

When a small force F is applied on the plunger in the downward direction, a pressure is produced on the liquid in contact with the plunger. This pressure is transmitted equally in all directions and acts on the ram in the upward direction as shown in Fig.1.The heavier weight placed on the ram is then lifted up.

Let

W = Weight to be lifted,

F= Force applied on the plunger

A= Area of ram.

a = Area of plunger

p = pressure intensity produced by force F

= force F/ Area of plunger = F/a

Due to Pascal's law, the above intensity of pressure will be equally transmitted in all directions.

Hence, the pressure intensity at the ram will be = p = F/a

But the pressure intensity on ram is also = (Weight /Area of ram) =W/A

Equating the pressure intensity on ram = F/a = W/a

Therefore W = [F/a] × A ...... (1)

Mechanical Advantage

The ratio of weight lifted to the force applied on the plunger is defined as the mechanical advantage. Mathematically, mechanical advantage is written as

M.A. = W/F..... (2)

Leverage of the Hydraulic Press

If a lever is used for applying force on the plunger, then a force F' smaller than F can lift the weight W as shown in fig. 2 .The ratio of L/*l* is called the leverage of the hydraulic press.

Taking moments about Q, $F' \times L = F \times l$

Therefore $F = F' \times (L/l)$.... (3)

Substituting the valued of F in equation (1), we get the expression for weight lifted as

$W = F = [F' \times (L/l)] \times (A/a) = F' \times (L/l) \times (A/a)$.... (4)

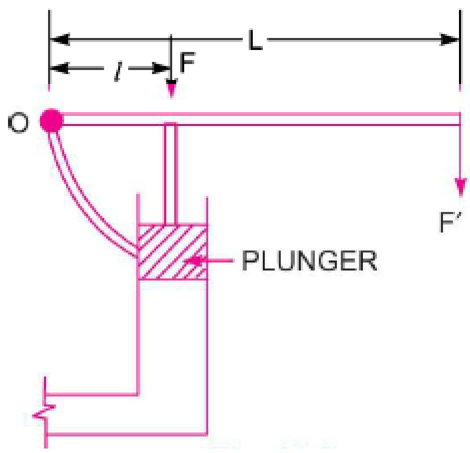

Fig.2 The hydraulic press

Actual Heavy Hydraulic Press

Based on the nature of the work required, actual hydraulic press is different in shape. But all actual hydraulic press consist of a ram sliding in a cylinder to which high-pressure liquid is forced.

Fig.3 shows one of the actual hydraulic press. It consists of a fixed cylinder in which a ram is sliding. To the lower end of the ram, movable plate is attached. As the ram moves up and down, the movable plate attached to the ram also moves up and down between two fixed plates. When any liquid under high pressure is supplied into the cylinder, the ram moves in the downward direction and exerts a force equal to the product of intensity of pressure supplied and area of the ram, on any material placed between the lower fixed plate and the movable plate. Thus the material gets pressed.

To bring back the ram in the upward position, the liquid from the cylinder is taken out. Then by the action of the return weight, the ram along with the movable plate will move up.

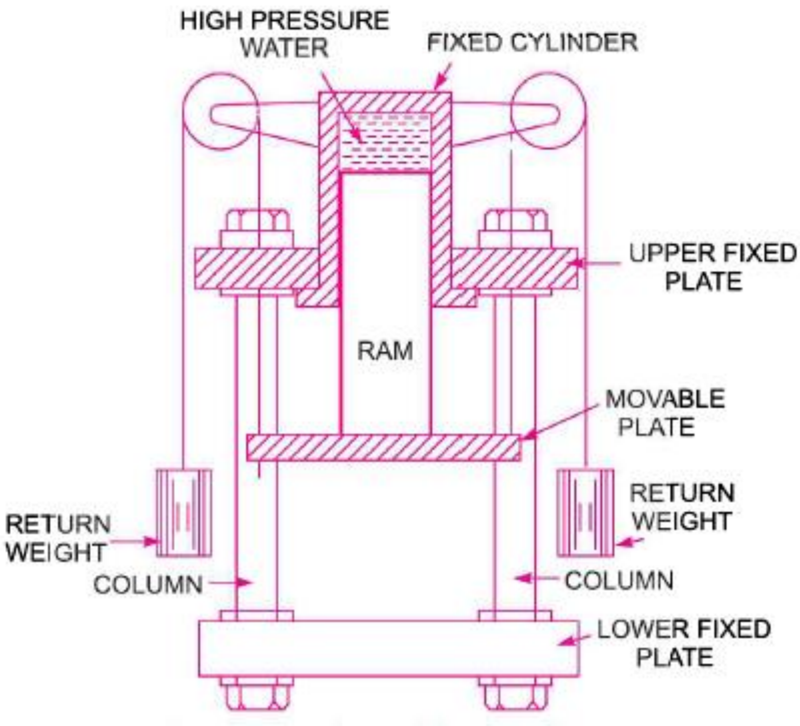

Fig.3 Actual hydraulic press

Q.1. A hydraulic press has a ram of 300 mm diameter and a plunger of 45 mm diameter. Find the weight lifted by the hydraulic press when the force applied at the plunger is 50 N.

Solution. Given :

Diameter of ram, $D = 300 \text{ mm} = 0.30 \text{ m}$

Diameter of plunger, $d = 45 \text{ mm} = 0.045 \text{ m}$

Force on plunger, $F = 50 \text{ N}$

Let weight lifted $= W \text{ N}$

Area of ram, $A = \frac{\pi}{4} D^2 = \frac{\pi}{4} (0.30)^2 = 0.07068 \text{ m}^2$

Area of plunger, $a = \frac{\pi}{4} d^2 = \frac{\pi}{4} (.045)^2 = .00159 \text{ m}^2$

The weight lifted (W) is given by equation (21.1) as

$$W = \frac{F}{a} \times A = \frac{50 \times .07068}{.00159} = \mathbf{2222.64 \text{ N. Ans.}}$$

Q.2. A hydraulic press has a ram of 200 mm diameter and a plunger of 30 mm diameter. It is used for lifting a weight of 3 kN. Find the force required at the plunger.

Solution. Given :

Diameter of ram, $D = 200 \text{ mm} = 0.20 \text{ m}$

$\therefore$ Area of ram, $A = \frac{\pi}{4} D^2 = \frac{\pi}{4} \times (0.20)^2 = 0.0314 \text{ m}^2$

Diameter of plunger, $d = 30 \text{ mm} = .03 \text{ m}$

$\therefore$ Area of plunger, $a = \frac{\pi}{4} (.03)^2 = 7.068 \times 10^{-4} \text{ m}^2$

Weight lifted, $W = 3 \text{ kN} = 3 \times 1000 = 3000 \text{ N}.$

Let the force on plunger $= F.$

Using relation given equation (21.1),

$$W = \frac{F}{a} \times A$$

$$F = \frac{W \times a}{A} = \frac{3000 \times 7.068 \times 10^{-4}}{.0314} = \mathbf{67.52 \text{ N. Ans.}}$$

Q.3. If in the problem 2, a lever is used for applying force on the plunger, find the force required at the end of the lever if the ration l/L is 1/10.

Solution. Given :

$$D = 0.20 \text{ m}, \; A = 0.0314 \text{ m}^2$$
$$d = 0.03 \text{ m}, \; a = 7.068 \times 10^{-4} \text{ m}^2$$

$$W = 3000 \text{ N}, \frac{l}{L} = \frac{1}{10}$$

Let F' = Force required at the end of the lever.

Using equation (21.4), $$W = F' \times \frac{L}{l} \times \frac{A}{a}$$

$$\therefore \quad F' = W \times \frac{l}{L} \times \frac{a}{A} = 3000 \times \frac{1}{10} \times \frac{7.068 \times 10^{-4}}{0.0314} = \textbf{6.752 N. Ans.}$$

Q.4. If in the problem 1, the stroke of the plunger is 100 mm, the distance travelled by the weight in 100 strokes. Determine the work done during 100 strokes.

Solution. The data given in problem 21.1 :

$$D = 0.30 \text{ m}, A = 0.07068 \text{ m}^2, d = 0.045 \text{ m}, a = .00159 \text{ m}^2$$

$$F = 50 \text{ N and } W \text{ (calculated)} = 2222.64 \text{ N}$$

Stroke of plunger $= 100 \text{ mm} = 0.10 \text{ m}$

Number of strokes $= 100$

Volume of liquid displaced by plunger in one stroke

$= \text{Area of plunger} \times \text{Stroke of plunger}$

$= a \times 0.10 \text{ m}^3 = .00159 \times 0.10 = .000159 \text{ m}^3.$

The liquid displaced by plunger will enter the cylinder in which ram is fitted and this liquid will move the ram in the upward direction.

Let the distance moved by the ram or weight in one stroke

$= x$ m

Then volume displaced by ram in one stroke

$= \text{Area of ram} \times x = A \times x = 0.07068 \times x \text{ m}^3$

As volume displaced by plunger and ram is the same,

$$\therefore \quad .000159 = .07068 \times x$$

$$\therefore \quad x = \frac{.000159}{.07068} = .00225 \text{ m}$$

$\therefore$ Distance moved by weight in 100 strokes

$= x \times 100 = .00225 \times 100 =$ **0.225 m. Ans.**

Work done during 100 strokes $= \text{Weight lifted} \times \text{Distance moved}$

$= W \times 0.225 = 2222.64 \times 0.225 \text{ Nm} =$ **500.094 Nm. Ans.**

Q.5. A hydraulic press has a ram of 150 mm diameter, plunger of 20 mm diameter. The stroke of the plunger is 200 mm and weight lifted is 800 N.If the distance moved by the weight is 1.0 m in 20 minutes determine:

(i) The force applied on the plunger (ii) Power required to drive the plunger

(iii) Number of strokes performed by the plunger.

Solution. Given :

Diameter of ram, $D = 150$ mm $= 0.15$ m

Diameter of plunger, $d = 20$ mm $= 0.02$ m

Stroke of plunger $= 200$ mm $= 0.20$ m

Weight lifted, $W = 800$ N

Distance moved by weight $= 1.0$ m

Time taken by weight $= 20$ minutes

Now, area of ram, $A = \frac{\pi}{4} D^2 = \frac{\pi}{4} (.15)^2 = 0.01767 \text{ m}^2$

Area of plunger, $a = \frac{\pi}{4} (.02)^2 = .00031416 \text{ m}^2$.

(*i*) Let the force applied on the plunger $= F$.

Using equation (21.1), we have $W = \frac{F}{a} \times A$

$$\therefore \quad F = \frac{W \times a}{A} = \frac{800 \times .00031416}{.01767} = \textbf{14.22 N. Ans.}$$

(*ii*) Work done by the press per second

$$= \frac{\text{Weight lifted} \times \text{Distance travelled}}{\text{Time}}$$

$$= \frac{800 \times 1.0}{20 \times 60} = 0.6667 \text{ Nm/s}$$

$\therefore$ Power required to drive the plunger

$$= \frac{\text{Work done per sec}}{1000} = \frac{0.6667}{1000} = \textbf{0.000666 kW. Ans.}$$

(*iii*) Volume of liquid displaced by plunger in one stroke

$= $ Area of plunger $\times$ Stroke length

$= .00031416 \times 0.20 = .000062832 \text{ m}^3$

Total volume of liquid displaced in cylinder

$= $ Area of ram $\times$ Distance moved by weight

$= .01767 \times 1.0 = 0.01767 \text{ m}^3$

$\therefore$ Number of strokes performed by plunger or pump

$$= \frac{\text{Total volume of liquid displaced}}{\text{Volume of liquid displaced per stroke}}$$

$$= \frac{0.01767}{.000062832} = 281.22 \simeq \textbf{281. Ans.}$$

THE HYDRAULIC ACCUMLATOR

The hydraulic accumulator is a device used for storing the energy of a liquid in the form of pressure energy, which may be supplied for any sudden or intermittent requirement. In case of hydraulic lift or the hydraulic crane, a large amount of energy is required when lift or crane is moving upward. This energy is supplied from hydraulic accumulator. But when the lift is moving in the downward direction, no large external energy is required and at that time, the energy from the pump is stored in the accumulator.

Fig.4 shows a hydraulic accumulator which consists of a fixed vertical cylinder containing a sliding ram. A heavy weight is placed on the ram. The inlet of the cylinder is connected to the pump, which continuously supplies water under pressure to the cylinder. The outlet of the cylinder is connected to the machine (which may be lift or crane etc.)

The ram is at the lowermost position in the beginning. The pump supplies water under pressure continuously. If the water under pressure is not required by the machine (lift or crane), the water under pressure will be stored in the cylinder. This will raise the ram on which a heavy weight is placed. When the ram is at the uppermost position, the cylinder is full of water and accumulator has stored the maximum amount of pressure energy. When the machine (lift or crane) requires a large amount of energy, the hydraulic accumulator will supply this energy and ram will move in the downward direction.

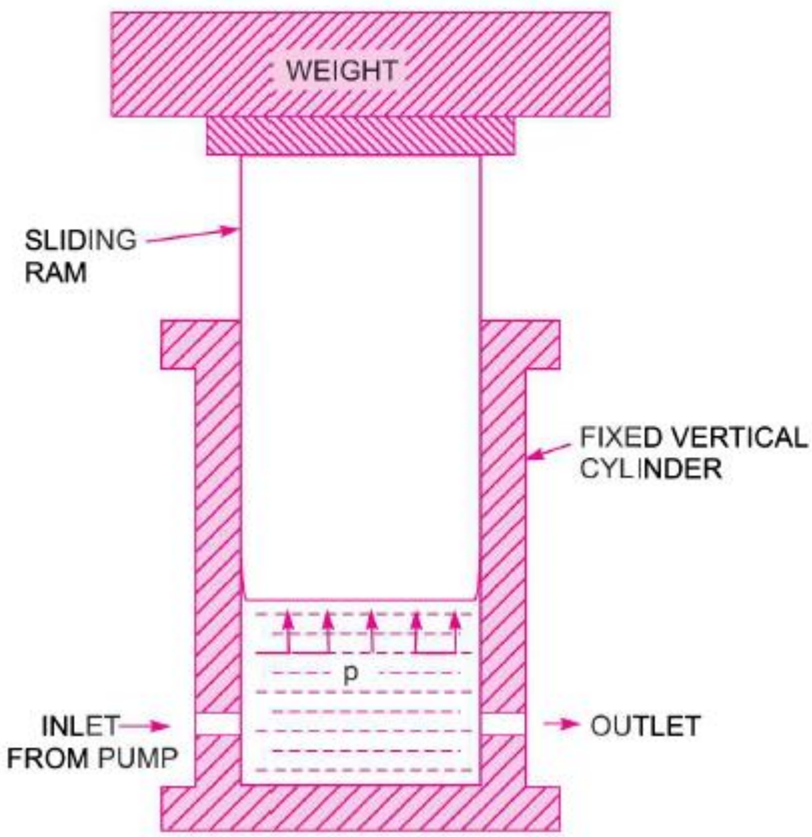

Fig.4 .The hydraulic accumulator

Capacity of Hydraulic accumulator

It is defined as the maximum amount of hydraulic energy stored in the accumulator. The expression for the capacity of accumulator is obtained as:

Let A = Area of the sliding ram,

L = Stroke or lift of the ram,

p = Intensity of water pressure supplied by the pump, and

W = Weight placed on the ram (including the weight of ram)

W = Intensity of pressure × Area of ram

Then = p × A

The work done in lifting the ram = W × Lift of ram = WL

= p × A × L (W = p× A)

The work done in lifting the ram is also the energy stored in the accumulator. And energy is equal to the capacity of the accumulator.

Therefore Capacity of accumulator = Work done in lifting the ram

= p × A × L ..... (5)

But A× L = Volume of accumulator

Therefore Capacity of accumulator = p × Volume of accumulator ..... (6)

Q.6. Determine the length of stroke for an accumulator having a displacement of 115 litres. The diameter of the plunger is 350 mm.

Solution. Given :

Displacement $= 115 \text{ litres} = 0.115 \text{ m}^3$

or Volume of accumulator $= 0.115 \text{ m}^3$

Dia. of plunger, $D = 350 \text{ mm} = 0.35 \text{ m}$

∴ Area of plunger, $A = \frac{\pi}{4} D^2 = \frac{\pi}{4} \times .35^2 \text{ m}^2$

But volume of accumulator $= A \times L$

where L = length of stroke.

∴ Volume $= \frac{\pi}{4} D^2 \times L$ or $0.115 = \frac{\pi}{4} \times (0.35)^2 \times L$

∴ $L = \frac{0.115 \times 4}{\pi \times 0.35^2}$ = **1.195 m. Ans.**

Q.7. The water is supplied at a pressure of 14 N/cm^2 to an accumulator, having a ram of diameter 1.5 m. If the total lift of the ram is 8 m, determine:

(i) The capacity of the accumulator

(ii) Total weight placed on the ram (including the weight of ram)

Solution. Given :

Supply pressure, $p = 14 \text{ N/cm}^2 = 14 \times 10^4 \text{ N/m}^2$

Dia. of ram, $D = 1.5$ m

$\therefore$ Area of ram, $A = \frac{\pi}{4} D^2 = \frac{\pi}{4} (1.5)^2 = 1.767 \text{ m}^2$

Lift of ram, $L = 8$ m.

(*i*) Capacity of accumulator is given by equation (21.5) as

Capacity $= p \times A \times L = 14 \times 10^4 \times 1.767 \times 8$

$= 1979.04 \times 10^3$ Nm = **1979.04 kNm. Ans.**

(*ii*) Total weight (W), placed on the ram is given by

$W = p \times A = 14 \times 10^4 \times 1.767$ N = **247380 N. Ans.**

Q.8. The total weight (including the self-weight of ram) placed on the sliding ram of a hydraulic accumulator is 40 kN. The diameter of the ram is 500 mm. If the frictional resistance against the movement of the ram is 5 % of the total weight ,determine the intensity of pressure of water when:

(i) The ram is moving up with a uniform velocity,and

(ii) The ram is moving down with uniform velocity.

Solution. Given :

Total weight, $W = 40 \text{ kN} = 40 \times 1000 = 40000$ N

Dia. of ram, $D = 500 \text{ mm} = 0.50$ m

$\therefore$ Area of ram, $A = \frac{\pi}{4} D^2 = \frac{\pi}{4} (.50)^2 = 0.1963 \text{ m}^2$

Frictional resistance against the movement of ram = 5% of total weight $= \frac{5}{100} \times 40000 = 2000$ N.

(*i*) *Intensity of pressure of water when ram is moving up with a uniform velocity.* When ram is moving up, the frictional resistance is acting opposite to the direction of movement of the ram, *i.e.*, frictional resistance is acting in the downward direction. Weight is also acting in the downward direction.

$\therefore$ Total force on the ram = Total weight + Frictional resistance

= 40000 + 2000 = 42000 N.

$$\therefore \text{ Pressure intensity } (p) = \frac{\text{Total force on ram}}{\text{Area of ram}} = \frac{42000}{0.1963}$$

$= 213958 \text{ N/m}^2 =$ **21.3958 N/cm². Ans.**

(*ii*) *Intensity of pressure when ram is moving down with a uniform velocity.* In this case, the frictional resistance is acting in the upward direction.

$\therefore$ Total force on the ram = Total weight – Frictional resistance

= 40000 – 2000 = 38000 N

$$\therefore \text{ Pressure intensity } (p) = \frac{\text{Total force}}{\text{Area}} = \frac{38000}{0.1963}$$

$= 193581 \text{ N/m}^2 =$ **19.3581 N/cm². Ans.**

Q.9. If in the problem 8 ,the stroke of the ram is 10 m and the ram falls through the full stroke in 4 minutes steadily,find the work done by the accumulator per second.If the pump,connected to the inlet of the accumulator,supplies 0.01 m^3/s at the same time,determine the work supplied by the pump per second and also power delivered by the accumulator to the hydrualic machine,connected at the outlet of the hydraulic accumulator,when ram is moving downwards.

Solution : 9 : The data from problem 8 , when ram is moving downward:

Total weight = 40000 N

Frictional resistance = 2000 N

Total force on ram = Total weight – Frictional resistance

= 40000 – 2000 = 38000 N

Area, $A = 0.1963\ m^2$

Pressure intensity of water when ram is moving downward

$p = 193581\ N/m^2$

Stroke of ram, $L = 10$ m

Time taken by ram to fall through full stroke, $t = 4$ minutes $= 4 \times 60 = 240$ s

Discharge supplied $Q = .01\ m^3/s$

$$\text{Distance moved by ram in one second} = \frac{\text{Stroke of ram}}{\text{Time}} = \frac{L}{t} = \frac{10}{240} = \frac{1}{24}\ \text{m/s.}$$

(*i*) Work done by accumulator per second

= Total force on ram × Distance moved by ram per sec

$$= 38000 \times \frac{1}{24} = \textbf{1583.33 Nm. Ans.}$$

(*ii*) Work supplied by the pump per sec = Weight of water supplied by pump per second × Head of supply pressure

$$= \rho g \times Q \times H = 1000 \times 9.81 \times .01 \times H \text{ Nm}$$

where H = Pressure head of water supplied $= \dfrac{p}{\rho \times g} = \dfrac{193581}{1000 \times 9.81} = 19.733$ m

∴ Work supplied by pump per sec $= 1000 \times 9.81 \times 0.01 \times 19.733 =$ **1935.81 Nm. Ans.**

(*iii*) Power delivered by the accumulator to the hydraulic machine connected at the outlet of accumulator

$$= \frac{1}{1000}\ \text{(Work done by accumulator per second + Work supplied by pump per second)}$$

$$= \frac{1}{1000}\ (1583.33 + 1935.81) = \textbf{3.519 kW. Ans.}$$

Q.10. An accumulator is loaded with 40 kN weight. The ram has a diameter of 30 cm and stroke of 6 m. Its friction may be taken as 5 %. It takes two min. to fall through its full stroke. Find the total work supplied and power delivered to the hydraulic appliance by the accumulator, when 7.5 lit/s is being delivered by a pump, while the accumulator descends with the stated velocity.

Solution. Given :

Total weight $= 40 \text{ kN} = 40 \times 1000 = 40000 \text{ N}$

Dia. of ram, $D = 30 \text{ cm} = 0.3 \text{ m}$

$\therefore$ Area of ram, $A = \frac{\pi}{4}(.3)^2 = 0.07068 \text{ m}^2$

Stroke of ram, $L = 6 \text{ m}$

Friction $= 5\%$

$\therefore$ Net load on accumulator (when it descends)

$= 40000 \times 0.95 = 38000 \text{ N}$

Time taken by ram to fall through full stroke, $t = 2 \text{ min} = 2 \times 60 = 120 \text{ sec}$

$\therefore$ Distance moved by ram per sec $= \frac{L}{t} = \frac{6}{120} = \frac{1}{20} \text{ m/s}$

Water supplied by pump $= 7.5 \text{ lit/s} = \frac{7.5}{1000} \text{ m}^3/\text{s} = .0075 \text{ m}^3/\text{s}$

Work supplied by accumulator per second

$= \text{Net load on ram} \times \text{Distance moved by ram per sec}$

$= 38000 \times \frac{1}{20} = 1900 \text{ Nm/s}$

Intensity of pressure of water, $p = \frac{\text{Net load}}{\text{Area}} = \frac{38000}{0.07068} = 542857 \frac{\text{N}}{\text{m}^2}$

Head due to pressure, $H = \frac{p}{\rho g} = \frac{542857}{1000 \times 9.81} = 55.337 \text{ m}$

Work supplied by pump per second = Weight of water supplied per second $\times$ Head of supplied pressure

$= \rho g \times Q \times H = 1000 \times 9.81 \times .0075 \times 55.337 = 4071.35 \text{ Nm/s}$

$\therefore$ Total work supplied per second to hydraulic machine

= Work supplied by accumulator and by pump

$= 1900 + 4071.35$ Nm/s = **5971.35 Nm/s. Ans.**

Power delivered to the hydraulic machine

$= \frac{\text{Total work supplied per sec}}{1000} = \frac{5971.35}{1000}$ = **5.9713 kW. Ans.**

DIFFERENTIAL ACCUMULATOR

It is a device in which the liquid is stored at a high pressure by a comparatively small load on the ram. It consists of a fixed vertical cylinder of small diameter as shown in fig.5.The fixed Vertical cylinder is surrounded by closely fitting brass bush, which is surrounded by an inverted moving cylinder, having circular projected collar at the base on which weights are placed.

The liquid from the pump is supplied to the fixed vertical cylinder. The liquid moves up through the small diameter of fixed vertical cylinder and then enters the inverted cylinder. The water exerts an upward pressure force on the internal annular area of the inverted moving cylinder, which is loaded at the base. The internal annular area of the inverted moving cylinder is equal to the sectional area of the brass bush. When the inverted moving cylinder moves up, the hydraulic energy is stored in the accumulator.

Let p = Intensity of pressure of liquid supplied by pump,

a = Area of brass-bush

L = Vertical lift of the moving cylinder

W = Total weight placed on the moving cylinder

Including the weight of cylinder

Then $W = p \times a$

Therefore $P = W/a$...... (7)

From equation (7), it is clear that pressure intensity can be increased with a small load W, by making area 'a' small.

Now total energy stored in the accumulator = Total weight × Vertical lift

$= W \times L$ Nm (7.1)

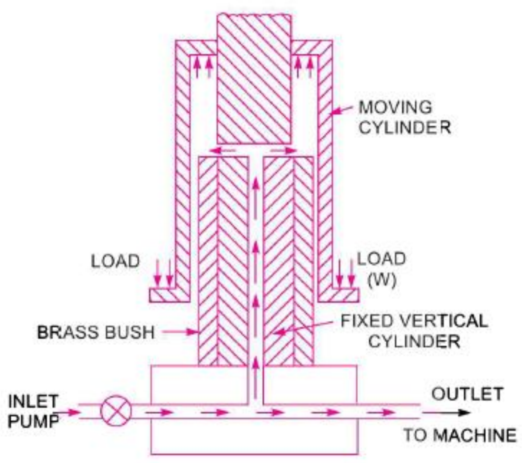

Fig.5. The differential hydraulic accumulator