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Subject: Turbomachinary

Unit: Fifth (Fluid System)

Topic: Hydraulic crane

THE HYDRAULIC CRANE

Hydraulic crane is a device, used for raising or transferring heavy loads. It is widely used in workshops, warehouses and dock sidings. A hydraulic crane consists of a mast, tie, jib, guide pulley and a jigger. The jib and tie are attached to the mast. The jib can be raised or lowered in order to decreases or increases the radius of action of the crane. The mast along with the jib can revolve about a vertical axis and thus the load attached to the rope can be transferred to any place within the area of the crane's action. The jigger, which consists of a movable ram sliding in a fixed cylinder, is used for lifting or lowering the heavy loads. One end of the ram is in contact with water and the other end is connected to set of movable pulley block. Another pulley block, called the fixed pulley block is attached to the fixed cylinder. The pulley block, attached to the ram, moves up and down while the pulley block, attached to the fixed cylinder, is not having any movement.

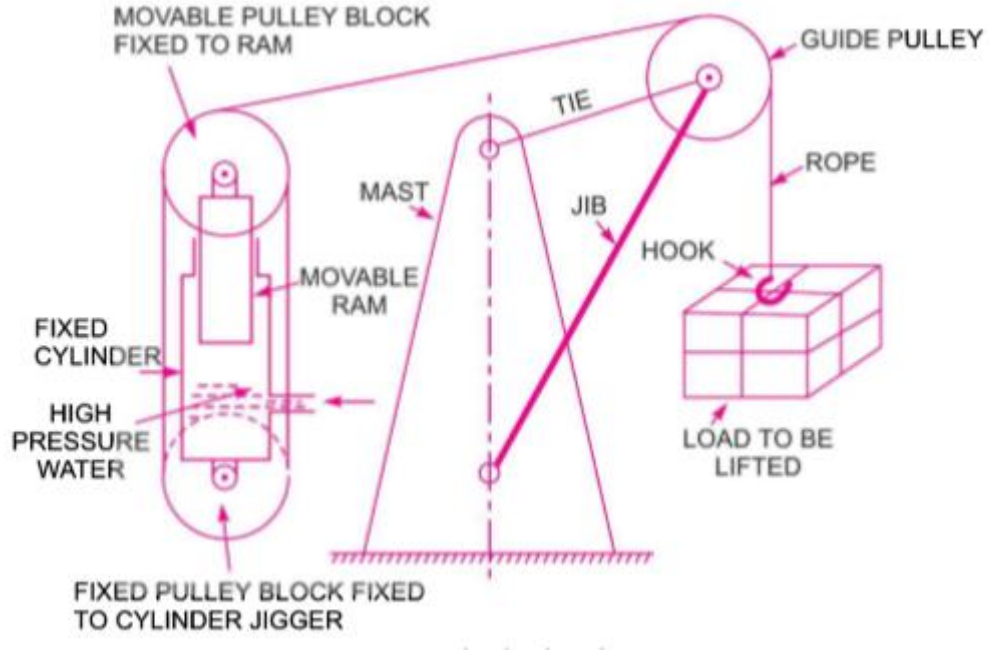

Fig. 5.21 The hydraulic crane

A wire rope, one end of which is fixed to a movable pulley (which is attached to the sliding ram) is taken round all the pulleys of the two sets of the pulleys and finally passes over the guide pulley, attached to the jib as shown in Fig. 5.21. The other end of the rope is provided with a hook, for suspending the load. For lifting the load by the crane, the water under high pressure is admitted into the cylinder of the jigger. This water forces the sliding ram to move vertically up. Due to the movement of the ram in the vertically up direction, the movable pulley attached to the ram also moves upward. This increases the distance between two pulley blocks and hence the wire passing over the guide pulley the jigger. This raises the load attached to the hook.

Efficiency of a hydraulic crane is given by,

$$\eta = \frac{Output}{input}$$

If W = Weight to be lifted, h = Height through which weight lifted

P = Pressure of water, A = Area of ram

L = Volume displaced,

Then, efficiency of the hydraulic crane will be

$$\eta = \frac{W \times h}{p \times A \times L} = \frac{Weight \times Distance\ moved\ by\ weight}{Force \times Distance\ moved\ by\ the\ force}$$

1. **Find the efficiency of a hydraulic crane, which is supplied 300 litres of water under a pressure of 60 N/cm^2 for lifting a weight of 12 kN through a height of 11m.**

Solution. Given:

Water supplied, Q = 300 litres = 0.30 m^3

Pressure, p = 60 × 10^4 N/m^2

Weight lifted, W = 12 kN = 12 × 1000 = 12000 N

Height, h = 11 m

Output of the crane = Weight lifted × Height through which weight is lifted

= W× h = 12000 × 11 Nm

Input of the crane = Energy supplied by the water

= Work done by water on the ram

= Force on the ram × Distance moved by ram

= Pressure × Area of the ram × Stroke of ram

= p × A × L

= 60 × 10^4 × Volume displaced

= 60 × 10^4 × 0.30 (∵ A× L = Q)

= 18 × 10^4 Nm

∴ Efficiency of the crane $= \frac{Output}{Input} = \frac{12000 \times 11}{18 \times 10^4} = 0.7333 = 73.33\%$ **Ans.**

2. The efficiency of a hydraulic carne, which is supplied water under a pressure of 70 N/cm^2 for lifting a weight through a height of 10m, is 60%. If the diameter of the ram is 150mm and velocity ratio is 6, Find

(i) The weight lifted by the crane, and

(ii) **The volume of water required in litres to lift the weight**.

Solution. Given :

Efficiency, $\eta = 60\% = 0.60$

Pressure of water, $p = 70 N/cm^2 = 70 \times 10^4 N/m^2$

Height through which weight is lifted, $h = 10m$

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

∴ Area of ram, $A = \pi r^2 = \pi (0.15)^2 = 0.01767 \ m^2$

Velocity ratio $= 6$

Pressure force on ram, P = Pressure × Area of ram

$= p \times A = 70 \times 10^4 \times 0.01767 = 12369$ N.

(i) We know efficiency of the hydraulic crane is given as

$$\eta = \text{Output/input} = \frac{Weight \times Distance\ moved\ by\ weight}{force \times Distance\ moved\ by\ force}$$

or $$0.60 = \frac{W \times distance\ moved\ by\ weight}{P \times Distance\ moved\ by\ force}$$

But $$\frac{Distance\ moved\ by\ weight}{Distance\ moved\ by\ force} = Velocity\ ratio = 6$$

∴ $0.60 = W/P \times 6 = (W/12369) \times 6$

∴ $W = (0.60 \times 12369)/6 = 1236.9$ N. Ans.

(ii) Volume of water required to lift the weight :

Velocity ratio $= \frac{Distance\ moved\ by\ weight}{Distance\ moved\ by\ force\ on\ ram}$

Or $60 = \frac{h}{stroke\ of\ ram}$ (∵ Distance moved by ram = Stoke of ram)

∴ Stroke of ram, $L = h/6 = 10/6 = 1.667m$

∴ Volume of water = Area of ram × stroke of ram

$= A \times L = 0.01767 \times 1.667$

$= 0.02945\ m^3 = 0.02945 \times 1000$

$= 29.45$ litres. Ans

3. A hydraulic crane is lifting a weight of 12000 N through a height of 12 m with a speed of 18 m per minute once in every two minutes. The efficiency of the hydraulic crane is 65% and it is working under a pressure of 500N/cm^2 of water. The crane is fed from an accumulator to which water is supplied by a pump. Find :
   (i) the capacity of the cylinder of the jigger in litres,
   (ii) The capacity of the accumulator in litres, and
   (iii) Minimum power required for the pump.

Solution. Given:

Weight lifted, W = 12000 N

Height, h= 12m

Speed of weight, V= 18m/min

No. of times the weight if lifted = Once in every two minutes

Efficiency, $\eta = 65\% = 0.65$

Pressure of water, $p = 500 N/cm^2 = 500 \times 10^4 N/m^2$

= Weight lifted × Height

= W × h = 12000 × 12 = 144000Nm

Input of crane = Work done by water on ram

= Force on ram × Distance moved by ram

= p × A × L

= p × Volume of cylinder ($\because$ A × L = Volume of cylinder)

= 500 × 10^4 × Volume of cylinder

$$\therefore \quad \eta = \frac{Output}{Input} = \frac{144000}{500 \times 10^4 \times Volume\ of\ cylinder}$$

$$\therefore \text{Volume of cylinder} = \frac{144000}{500 \times 10^4 \times \eta} = \frac{144000}{500 \times 10^4 \times 0.65} = 0.0443 m^3 = 44.3 \text{ litres}$$

$\therefore$ Capacity of the cylinder of the jigger = 44.3 litres. Ans.

(iii) Input of the crane = p × Volume of cylinder = 500 × 10^4× 0.0443
= 221500 Nm.

This input is given to the crane once is every two minutes.

∴ Input to crane per min. $== \frac{221500}{2} = 110750\ Nm.$

The weight 12000 N is lifted to a height of 12 m with a speed of 18m/min.

Time required to lift the weight through height of 12 m = $\frac{height}{speed} = \frac{12}{18} = \frac{2}{3} min.$

∴ Work done by the pump during lifting

= Work done per min. × Time required to lift the weight

= 110750 × 2/3 = 73833.33 Nm

∴ Energy supplied by accumulator

= Total input energy to the crane – Work done during lifting

= 221500 – 73833.33 = 147666.67 Nm (i)

But energy supplied by accumulator = Force on the ram of accumulator × Lift of ram

= p× A × H = P × Capacity of accumulator

= 500 × 10^4 × Capacity of accumulator (ii)

Equating the two values given by equations (i) and (ii),

147666.67 = 500 × 10^4 × Capacity of accumulator

∴ Capacity of accumulator = $\frac{147666.67}{500 \times 10^4} = 0.0295 m^3 = 29.5\ Litres. Ans.$

(iii) Minimum power required for the pump

$$= \frac{Work\ input\ per\ minute}{1000\ \times 60} = \frac{110750}{1000 \times 60} = 1.846\ kW. Ans.$$