Drilling Engineering II

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Module I, Lecture 2

(An Overview of Drilling Engineering 2)

The Mud Pumps Cont.

Pump Factor for Double Acting

Since both pistons make a stroke in each direction for each revolution of the crank, there are four individual piston strokes per crank revolution. Therefore, for N revolution, Eq. (5) can be obtained as:

$$q_{DN} = \frac{\pi\, L_s\, \eta_p}{2} \times \left\{ 2d_l^2 - d_{pr}^2 \right\} \times 4N \qquad (6)$$

Hydraulic horsepower for double acting pump

Now, pumps are commonly rated by hydraulic horsepower. If we assume that suction pressure is atmospheric, then work done per piston stroke can be calculated as:

$$W_P = P_d \times \left[\frac{\pi}{4}\left(d_l^2 - d_{pr}^2\right)\frac{L_s}{12}\right] \quad (7)$$

where,

W_P = work done per piston stroke, $\mathrm{lb_f - ft}$
P_d = discharge pressure, psig

The Mud Pumps Cont.

Hydraulic horsepower for double acting pump Cont.

Since both pistons make a stroke in each direction for each revolution of the crank, there are four individual piston strokes per crank revolution. Therefore, for N revolution, Eq. (7) can be obtained as:

$$W_{PN} = P_d \times \left[\frac{\pi}{4}\left(d_l^2 - d_{pr}^2\right)\frac{L_s}{12}\right] \times 4N \qquad (8)$$

where,

W_{PN} = work done per complete stroke, $\mathrm{lb_f - ft}$

The Mud Pumps Cont.

Power output for Double Acting

The power output for pump then can be obtained as:

$$P_{out_p} = \frac{P_d \times \left[\frac{\pi}{4}\left(d_l^2 - d_{pr}^2\right)\frac{L_s}{12}\right] \times 4N}{\left(33{,}000\ ft - lb_f/min\right)\Big/_{hp} \times \eta_{mp}} = \frac{P_d\left(d_l^2 - d_{pr}^2\right)L_s\, N}{126050.4 \times \eta_{mp}} \qquad (9)$$

where,

W_{PN} = work done per complete stroke, $lb_f - ft$

P_{out_p} = output power for the duplex pump, hp

η_{mp} = mechanical efficiency of the duplex pump, %

For a mechanical efficiency of 85%, Eq. (9) can be reduced to the following equation:

$$P_{out_p} = \frac{P_d\left(d_l^2 - d_{pr}^2\right)L_s\, N}{107143} \qquad (10)$$

Single Acting Pump

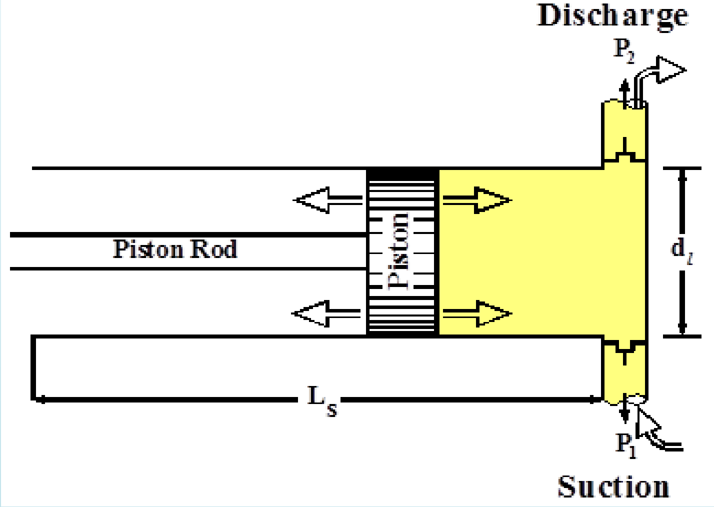


Figure 4b Single-acting design

For a single acting pump (triplex), there is only one suction and delivery valve which means there is no backward displacement. Therefore, the volumetric displacement by each piston stroke during one complete cycle is given by

$$q_S = \frac{\pi}{4} d_l^2 L_s \qquad (11)$$

The Mud Pumps Cont.

Single Acting Pump

Thus, the volumetric displacement per cycle for a single-acting pump having three cylinders with volumetric efficiency becomes as:

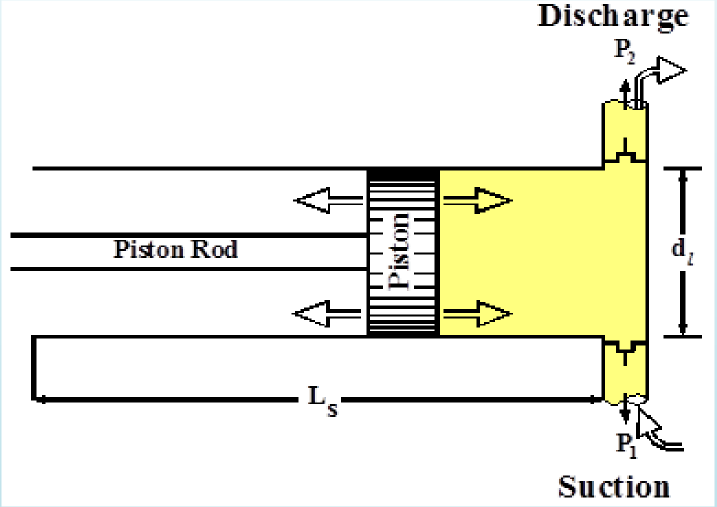


Figure 4b Single-acting design

$$q_{ST} = \frac{3\pi}{4} d_l^2 L_s \times \eta_p \qquad (12)$$

For N number of pump cycle, Eq. (12) can be written as:

$$q_{STN} = \frac{3\pi}{4} d_l^2 L_s \, \eta_p \times N \qquad (13)$$

The Mud Pumps Cont.

Example 1: Compute the pump factor in units of barrels per stroke for a duplex pump having 6.5-in. liners, 2.54-in. rods, 18-in. strokes and a volumetric efficiency of 90%?

Solution:

The pump factor for a duplex pump can be determined using Eq 4:

$$q_D = \frac{\pi\, L_s}{2} \times \{\, 2 d_l^2 - \, d_{pr}^2 \} \times \eta_p$$

$$= (\pi/2)\ 18\ [\ 2(6.5)^2 - (2.5)^2]\ *\ 0.9$$

$$= 1991.2 \text{ in.}^3 \text{/stroke}$$

$$= (1991.2 \text{ in.}^3 \text{/stroke})*(1 \text{ gal}/231 \text{ in}^3)*(1 \text{ bbl}/42 \text{ gal})$$

or $= \underline{0.2052 \text{ bbl/stroke}}$

The Mud Pumps Cont.

PUMP Rating

Pumps are rated for:

- Hydraulic Power
- Maximum Pressure
- Maximum Flow rate

$$P_H = \frac{\Delta P * q}{1714} \qquad (14)$$

where,

P_H = Pump Pressure, hp

ΔP = Increase in pressure, psi

q = Flow rate (gal/min)

Note: ΔP cannot be more than **3500** psi

Pump Problem

Example 2: Example Calculate the liner size required for a double-acting duplex pump where rod diameter is 2.5 in, stroke length is 22 in stroke, pump speed is 70 strokes/min. In addition, the maximum available pump hydraulic horsepower is 1200 hp. For optimum hydraulics, the pump recommended delivery pressure is 3,000 psi. Assume the volumetric efficiency of pump is 98%.

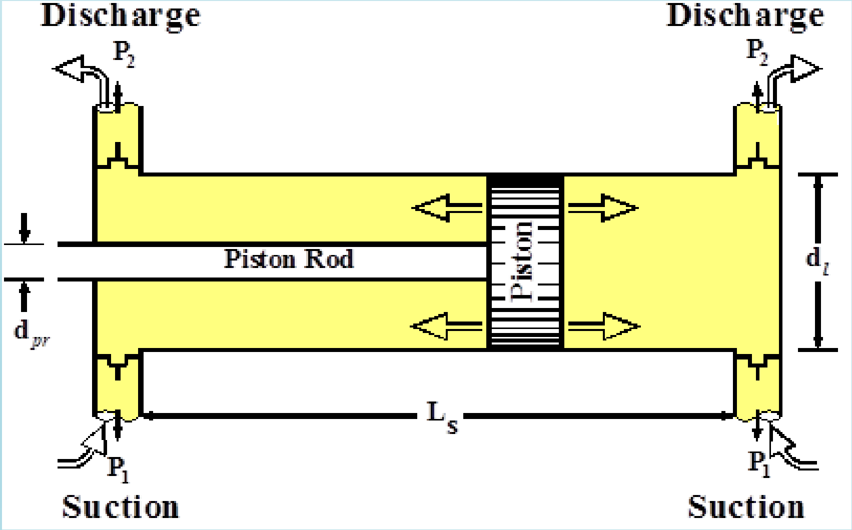


Figure 4a Double acting design

The Mud Pumps Cont.

Example 2: Solution Cont.

Given data:

d_{pr} = piston rod diameter, inch = 2.5 in

L_s = stroke length, inch = 22 in

$4N$ = revolutions per minute of crank = $\text{piston strokes/min}$

= 70 strokes/min

P_{out_p} = output power for the duplex pump, hp = 1,200 hp

P_d = discharge pressure, psig = 3,000 psi

(here it is Δp for the pump)

η_p = volumetric efficiency of pump = 0.98

Required data:

d_l = liner diameter, inch

The Mud Pumps Cont.

Example 2: Solution Cont.

Using Eq. (4), the pump displacement for a duplex pump is given by

$$q_D = \frac{\pi\, L_s}{2} \times \left\{ 2d_l^2 - d_{pr}^2 \right\} \times \eta_p = \frac{\pi \times (22\ in)}{2} \times \left\{ 2d_l^2 - (2.5\ in)^2 \right\} \times 0.98,\ {}^{in^3}/_{stroke}$$

$$= \left[33.85 \times \left\{ 2d_l^2 - (2.5\ in)^2 \right\}\ {}^{in^3}/_{stroke} \right] \times \frac{1\ gal}{231\ in^3} = \frac{\left\{ 2d_l^2 - (2.5\ in)^2 \right\}}{6.82}, \frac{gal}{stroke}$$

(***Note***: $1\ gal = 231\ in^3$)

Example 2: Solution Cont.

Using Eq. (6), the pump displacement for a duplex pump operating at 70 strokes/min is given by

$$q_{DN} = \frac{\pi\, L_s\, \eta_p}{2} \times \{\, 2d_l^2 - \; d_{pr}^2\} \times 4N = \frac{\{\, 2d_l^2 - \; (2.5\ in)^2\}}{6.82}, \frac{gal}{stroke} \times 70\ \frac{stroke}{min}$$
$$= \{20.53 d_l^2 - 64.15\}\ gpm$$

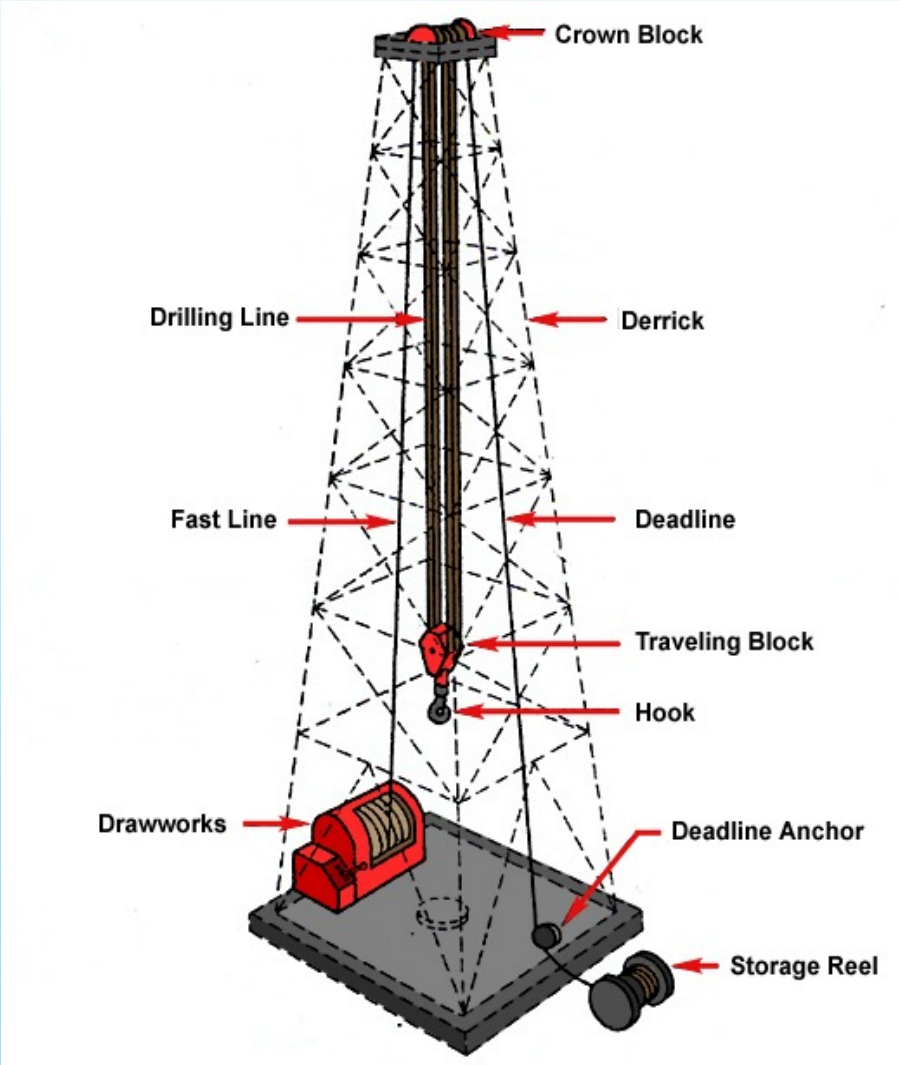
Equation (2.33) gives the pump displacement as

$$P_{hp} = \frac{\Delta p\ q}{1714} \Rightarrow 1{,}200\ hp = \frac{(3{,}000\ psi)\ q}{1714} \Rightarrow q = 685.6\ gpm$$

Theoretically, these two pump displacement is equal therefore,

$$q_{DN} = q\ \Rightarrow \{\, 20.53\ d_l^2 - 64.15\} = 685.6 \Rightarrow\ \boldsymbol{d_l = 6.04\ in}$$

Hoisting System



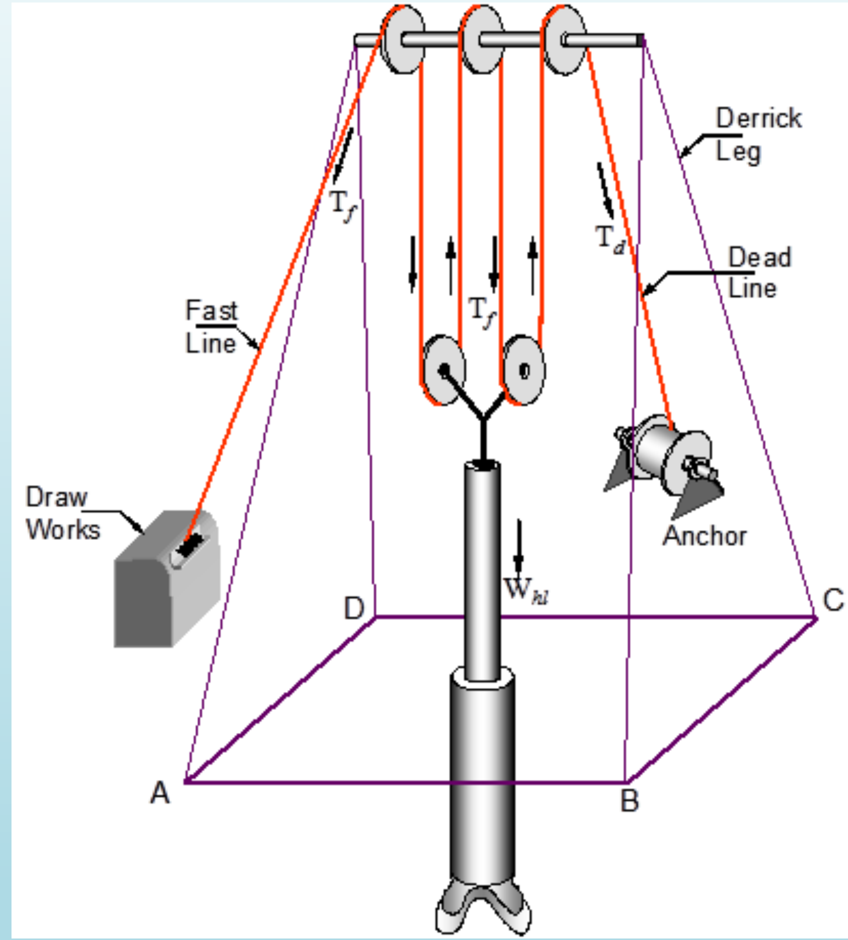


Figure 5 Hoisting system

Principal Function: To provide a mechanical advantage which permits easier handling of large loads.

$$M = \frac{W}{F_f} = \frac{\text{Load supported by travelling block}}{\text{Load imposed on the draw works}} \quad (15)$$

M= Mechanical advantage, F = tension in the fast line

The ideal mechanical advantage that assumes no friction in the block and tackle can be determined from a force analysis of the travelling block:

$$n F_f = W \quad (16)$$

$$M_i = \frac{W}{W/n} = n \quad (17)$$

M_i = ideal mechanical advantage

Hoisting System Cont..

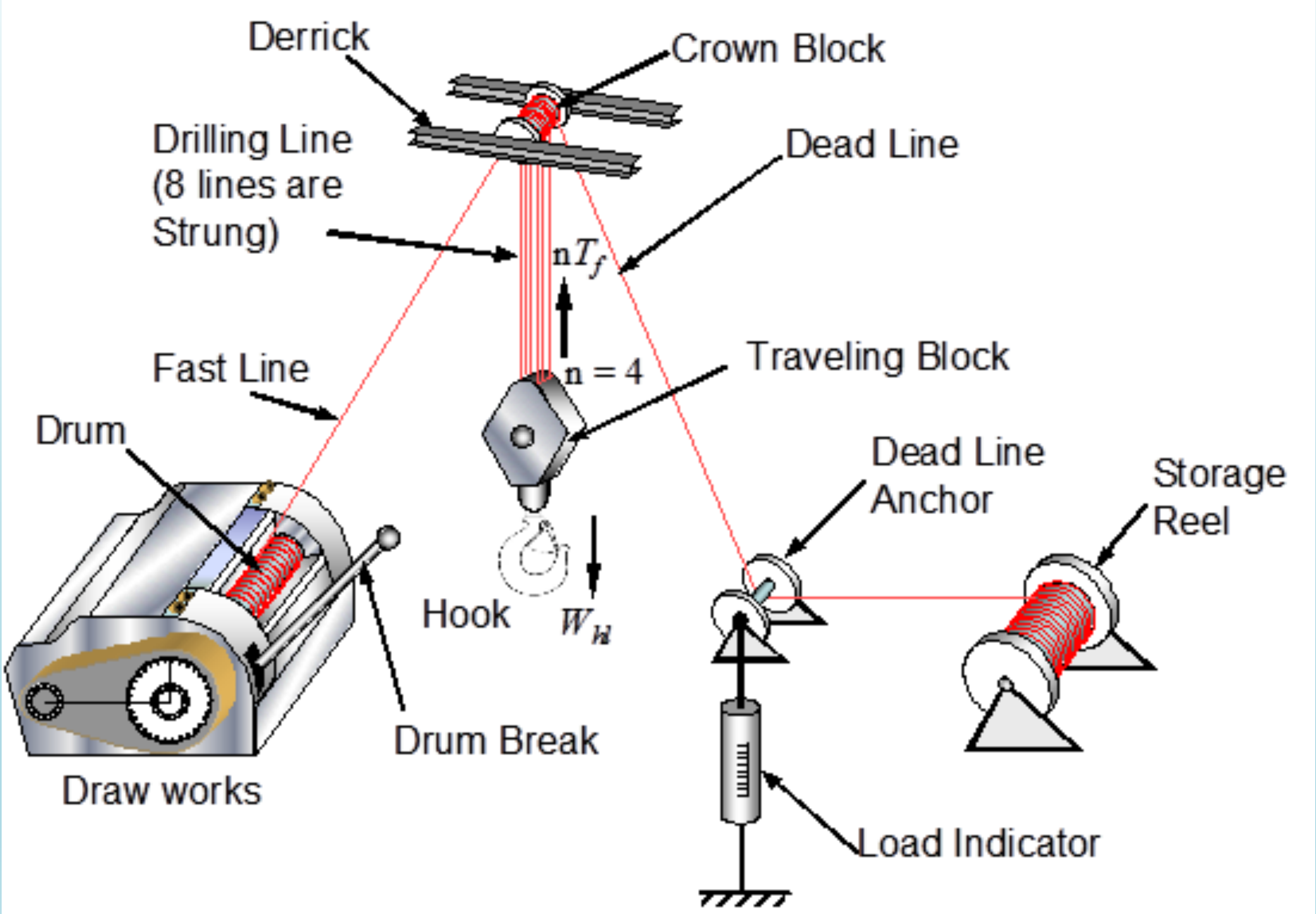


Figure 6 Schematics of Block and Tackle

Hoisting System Cont..

$$P_i = F_f \; V_f \qquad (18)$$

where,

P_i = Input power of block & tackle

F_f = draw works load

V_f = velocity of fast line

P_h = output power of the hook load

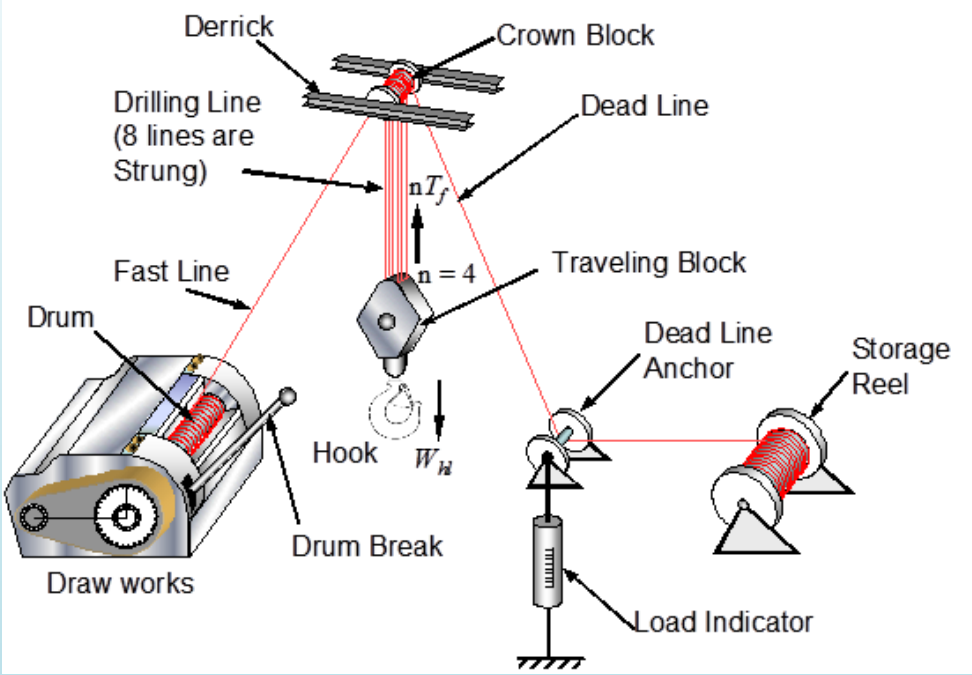


Figure 6 Schematics of Block and Tackle

$$P_h = W.V_b \qquad (19)$$

where,

W = travelling block load

V_b = velocity of travelling block

Hoisting System Cont..

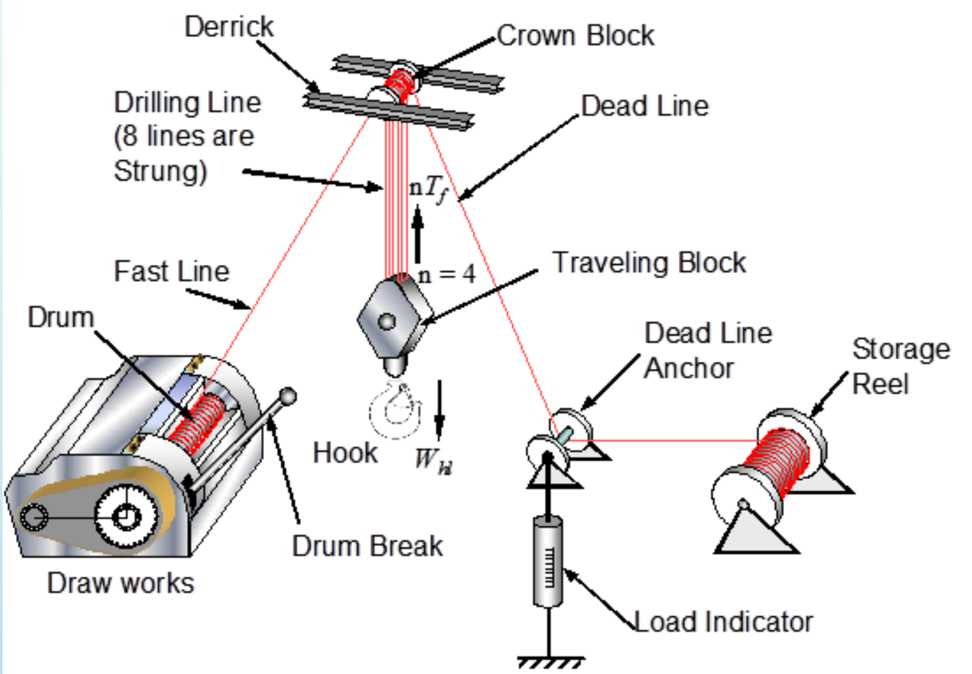


Figure 6 Schematics of Block and Tackle

$$V_b = \frac{V_f}{n} \qquad (20)$$

$$E = \frac{P_h}{P_i} = \frac{(nF_f)\cdot(V_f / n)}{F_f V_f} = 1 \quad no\ friction \qquad (21)$$

Hoisting System Cont..

Load on Derrick (Actual System)

Power efficiency is:

$$E = \frac{P_h}{P_i} = \frac{Wv_f / n}{F_f v_f} = \frac{W}{F_f n} \qquad (22)$$

Tension in the fast line:

$$F_f = \frac{W}{E_h} \qquad (23)$$

Hoisting System Cont..

Load on Derrick (friction in sheaves)

Derrick Load = Hook Load + Fast Line Load + Dead Line Load

$$F_d = W + F_f + F_{sx} \qquad (24)$$

$$F_d = W + \frac{W}{En} + \frac{W}{n} = \left(\frac{1 + E + En}{En}\right) W \qquad (25)$$

E = overall efficiency, e.g., $E = e^n = 0.98^n$

Hoisting System Cont..

Example 3: A rig must hoist a load of 300,000 lbf. The drawworks can provide an input power to the block and tackle system as high as 500 hp. Eight lines are strung between the crown block and traveling block. Assume that the rig floor is arranged as shown in Figure 6.

Calculate:

1. The static tension in the fast line when upward motion is impending
2. The maximum hook horsepower available
3. The maximum hoisting speed
4. The actual derrick load
5. The maximum equivalent derrick load
6. The derrick efficiency factor

Hoisting System Cont..

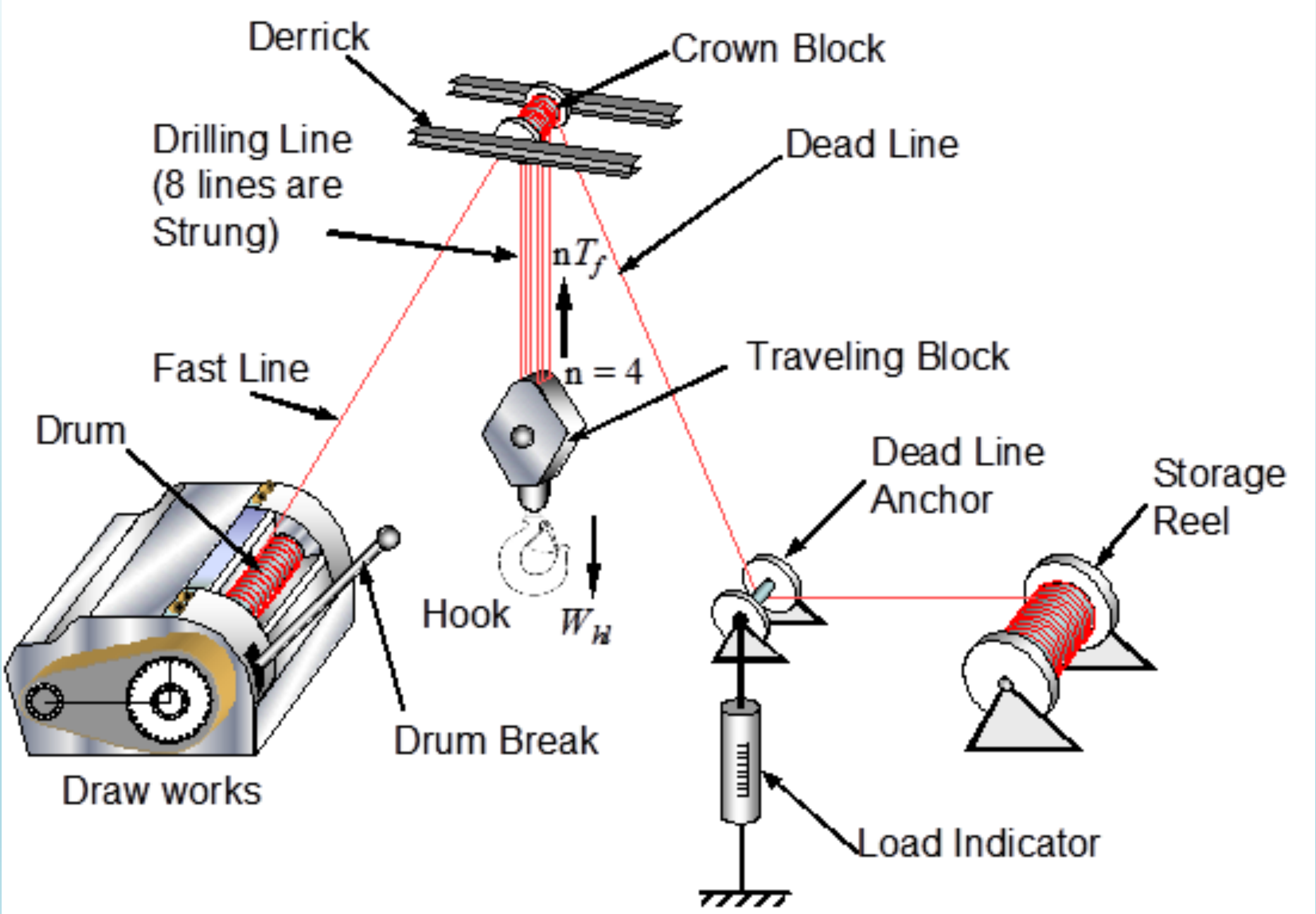


Figure 6 Schematics of Block and Tackle

Solution

1. The power efficiency for n = 8 is given as 0.841. The tension in the fast line is given as:

Tension in the Fast Line,

$$F = \frac{W}{E\ n} = \frac{300,000}{0.841*8} = 44,590\ lb$$

$(0.98^8 = 0.851)$

Example 3: Solution Cont.

2. The maximum hook horsepower available is

$$P_h = E \cdot p_i$$
$$= 0.841(500)$$
$$= \underline{420.5 \text{ hp}}$$

3. The maximum hoisting speed is given by

$$v_b = \frac{P_h}{W}$$

$$= \frac{420.5 \text{ hp} \left(\dfrac{33{,}000 \text{ ft-lbf/min}}{\text{hp}} \right)}{300{,}000 \text{ lbf}}$$

$$= \underline{46.3 \text{ ft/min}}$$

Example 3: Solution Cont.

To pull a 90-ft stand would require

$$t = \frac{90 \text{ ft}}{46.3 \text{ ft / min}} = 1.9 \text{ min.}$$

4. The actual derrick load is given by :

$$F_d = \left(\frac{1 + E + En}{En} \right) W$$

$$= \left(\frac{1 + 0.841 + 0.841(8)}{0.841(8)} \right) (300{,}000)$$

$$= \underline{382{,}090 \text{ lbf.}}$$

Example 3: Solution Cont.

5. The maximum equivalent load is given by :

$$F_{de} = \left(\frac{n+4}{n}\right) W = \left(\frac{8+4}{8}\right) * 300{,}000$$

$$F_{de} = \underline{450{,}000 \;\; lbf}$$

6. The derrick efficiency factor is:

$$\mathrm{E_d} = \frac{\mathrm{F_d}}{\mathrm{F_{de}}} = \frac{382{,}090}{450{,}000}$$

$$\mathrm{E_d} = 0.849 \text{ or } 84.9\%$$

Good Luck

and

Thanks for Being with my Couse

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