Artificial Lift

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Lecture-29 SRP- Pump Performance Analysis-Part-2

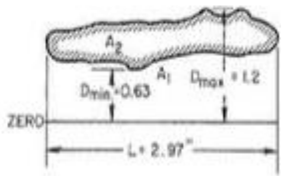
This problem involves using the dynamometer card to assess how much force is required, including the maximum force, minimum force, and counterbalance force. If you have the ideal curve, D_{max} will look completely like this one or maybe slightly smaller. However, when you have the actual dynamometer curve, it won't be completely rectangular, and a straight line won't exist. Initially, the curve may appear like this, then go like this, and then like this because it's a combination of many factors. So, this may be your curve, and the area under this curve indicates how much force you need in the motor or IC engine to keep your system running.

Some parameters are provided: $d_{minimum}$ is 0.63 inches, $d_{maximum}$ is 1.2 inches, L is 2.97 inches, and areas A_1 and A_2 are given as 2.1 square inches and 1.14 square inches, respectively. L is provided as 2.97 inches, and a calibration constant is required because you want to calculate based on whether you have a smaller curve or a more prominent curve. To calculate, you need to know the calibration constant. Manufacturers of pumps or dynamometers should provide this calibration constant. In this case, a constant of 12,800 pounds per inch is given, and the stroke length is 45 inches, with a speed of 18.5 SPM (Strokes Per Minute). They are asking you to calculate the maximum load. There are some basic formulas: the formula for maximum load is C multiplied by d1, and the formula for mean load is C multiplied by d_2. So, to find the minimum and maximum load, multiply C by d_{mean}.

The range of load equals C times d_1 minus d_2. The upstroke load is C multiplied by A_1 plus A_2 divided by L, which represents the average downstroke load and equals C born by d_3. The counterbalance load equals half the average upstroke load and the average downstroke load.

The polished rod horsepower is calculated as C multiplied by A_2 divided by L, then multiplied by S, and finally multiplied by 33,000 divided by 12. Here, L represents the length of the card, S is the stroke length, and SPM is the strokes per minute.

Dmax=1.2
Dmin=0.63"
A1=2.1 in2
A2=1.14 in2
L=2.97"
C= calibration constt.
=12800 lb/in
S= 45in
N=18.5 spm



Calculate

a) Max load
b) Min load
c) Av upstroke load
d) Av down stroke load
e) Corrected counter balance
f) HP of polished rod

max load $= CD_1 = 12800 \times 1.2 = 15400$ lb

min $= CD_2 = 12800 \times 0.63 = 8100$ lb

Range $= C(D_1 - D_2)$

Average upstroke load $= C\left(\frac{A_1 + A_2}{L}\right) = 4800$ lb

down stroke " $= CD_3 = 9100$ lb

Actual counter balance load $= \frac{1}{2}$ (Average upstroke load + Average down stroke load

Polish rod HP $= C(A_2/L) \cdot \frac{SN}{33000 \times 12}$

correct counter balance

$= C\left(\frac{A_1 + A_2/2}{L}\right) = 11500$ lb

PRHP = 10.3.

Now, let's proceed with the calculations. The maximum load is calculated as C times d_1, which equals 12,800 multiplied by 1.2, resulting in 14,560 pounds. The minimum load is calculated as C times d1 or d max or d mean, which equals 12,800 multiplied by 0.63, resulting in 8,064 pounds. The range is not required for this calculation.

The average upstroke load is calculated as 14,800 based on the given values for A_1 and A_2. The average downstroke load is calculated as C times A_1 divided by L, which equals 9,100 pounds.

The correct counterbalance mass is calculated as C times A_1 plus A_2 divided by 2, divided by L, which equals 11,500 pounds. Therefore, the polished rod horsepower (HP) is 10.3.

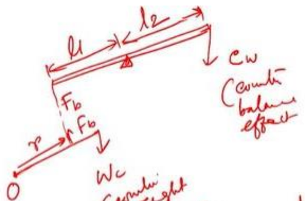
I encourage students to attempt similar problems to practice and solve assignment problems effectively.

As for the next part about the problem related to maximum and minimum loads in a pumping installation with various dimensions and weights, it seems there's a description of a diagram or drawing involved. If you have specific questions or need assistance with this part, please provide more details, and I'd be happy to help further.

So, CW equals Wc multiplied by d divided by R, d divided by R multiplied by L_1, and L_2 equals CT equals CS. Remember this formula: d divided by R multiplied by L1 divided by L_2. You need to solve the problem using this formula to find CS and CT. To do that, apply the formula CT equals CS times W_c times d divided by R plus L_1 divided by L_2. The values for L_1 and L_2 are given in the problem.

Now, for CS, you can derive the equation: CS equals CT minus Wc times d divided by R multiplied by L_1 divided by L_2, considering that L1 equals L2 as given in the problem. So, it simplifies to CS equals 10,000 (given CT value) minus 6,000 (given value for Wc) times 40 (given value for d) divided by 28 (given value for R) plus 1 (since L_1 equals L_2 in the problem). This simplifies to CS equals 9,500 pounds, and that's the answer for CS.

- The max and min loads for a pumping installation were determined from a dynamometer Card to be 15500 lb and 3500 lb, respectively. The well has a 2 in plunger on 7/8 in rod with a tubing anchor set at 5000 ft. Counter weights on the unit weight 6000lbs. The unit dimensions are d=40in, r=28in l1=l2. Actual total counterbalance effect is 10,000lbs. Determine the following:
- Structural unbalance, Cs
- Ideal counterbalance effect, Ct



Total counter balance effect, $C_t = C_s + C_w$

approx structural balance

$C_w = W_c\left(\frac{d}{r}\right)\left(\frac{l_1}{l_2}\right)$

$C_t = C_s + W_c\left(\frac{d}{r}\cdot\frac{l_1}{l_2}\right)$

$C_t = C_s + W_c\left(\frac{d}{r}\cdot\frac{l_1}{l_2}\right), l_1 = l_2$

$C_s = C_t - W_c\left(\frac{d}{r}\right)$

$= 10000 - 6000\left(\frac{40}{28}\right)$

$C_t = \frac{\text{max load} + \text{min load}}{2}$

$= \frac{15500 + 3500}{2}$

$= 9500$ lb.

Next, let's consider another problem taken from Kermit Brown's book. The pumping system has the following buoyant weight of the rod: W_2 = 10,000 pounds. Positive weight refers to the importance of the rod when it's immersed in water during pumping. It accounts for the buoyancy effect. Given that the fluid weighs 4,000 pounds, you must calculate the counterbalance (CB).

CB can be calculated as follows: CB = (W_f / 2) + W_2, where W_f is the fluid load and W_2 is the buoyant rod load. Substituting the values, you get CB = (4,000 / 2) + 10,000 = 12,000 pounds.

Now, let's consider the unbalanced force during the upstroke and downstroke. The unbalanced force (F_{up}) is calculated as F_{up} = upstroke load - counterbalance during the upstroke. So, F_{up} = 10,000 - 12,000 = -2,000 pounds.

Similarly, the unbalanced force (F_{down}) is calculated as F_{down} = counterbalance - downstroke load during the downstroke. So, F_{down} = 12,000 - 10,000 = 2,000 pounds.

Consider a pumping system as follows

Buoyant weight of rods, W2=10000 lb

Fluid weight Wf=4000 lb

Counter balance= Wf/2+W2=4000/2+10000=12000 lb

Unbalance force during upstroke = upstroke load-counterbalance

=10000-4000-12000=2000 lb

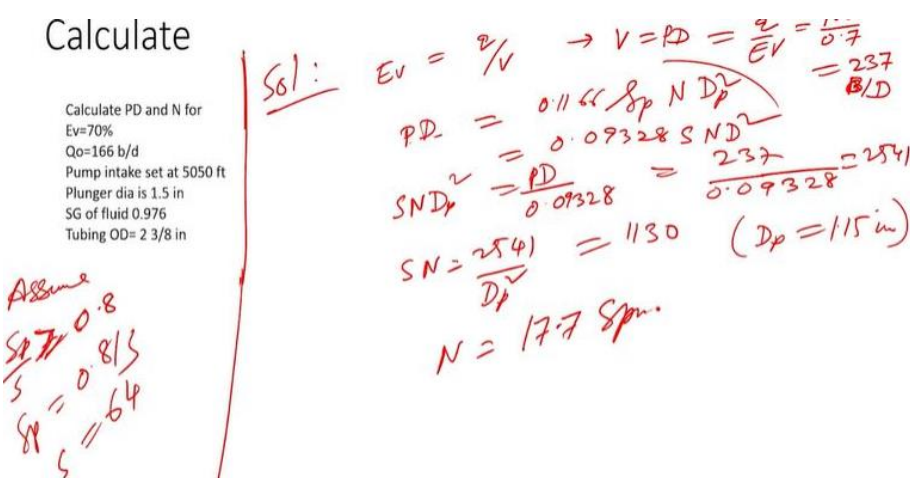
Downstroke

Counterbalance-downstroke load=unbalanced force

=12000-10000 = 2000 lb

Both the upstroke and downstroke unbalanced forces are the same. Whenever you calculate the unbalanced force in the counterbalance, that's the force the motor needs to provide. It's calculated based on the fluid weight and rod weight.

Let's consider another problem where we need to calculate the piston displacement, which tells us how much fluid is being delivered by the pump and also the speed in Strokes Per Minute (SPM). The given parameters include a volumetric flow rate of 70%, an oil flow rate of 166 barrels per day, a pump intake set at 5050, a plunger diameter of 1.5, the specific gravity of the fluid, as well as the outer diameter of the tubing. However, the inner diameter of the tubing is not provided, so we'll need to estimate it.



To calculate the piston displacement (P_D), we can use the formula $P_D = Q / EV$, where Q is the flow rate, and EV represents the efficiency value of 70% or 0.7 in decimal form. Plugging in the values, we get V = 166 / 0.7 = 237 barrels per day.

Note: There seems to be an inconsistency in the notation used for barrels per day (BD) and barrels (B). I'm using BD to represent barrels per day.

To find P_D, we can use the formula $P_D = 0.1166 * SP * NDP^2$, where SP is the fluid's specific gravity, and NDP is the plunger diameter squared. Given the specific gravity, we can calculate NDP^2 as 0.09328, and therefore, SND^2 equals P_D / D^2, where D represents the plunger diameter. With the given plunger diameter of 1.15 inches, SND equals 2541. Now, we can use this value to find SPM. Assuming SP by S equals 0.8, where S represents the tubing stretch, and if not given, we can make this assumption for simplicity (SPM = 64 inches), we can calculate N as 0, and N equals 17.7 SPM.

It's worth noting that the curve becomes slightly slanted if there's a tubing stretch. However, you measure the polished rod area in an ideal scenario. The pump card curve reflects the actual conditions. When you lift the plunger, the rod has an extension and other parameters change. Initially, when the standing valve opens, you need extra pressure to overcome the static condition of the standing valve, and you encounter various forms of friction.

You initially require very high pressure, it goes down, then up again, and down once more before going up, creating a waveform. While the ideal curve may appear as a complete rectangle or a perfectly straight line, this isn't how it happens. The TV (traveling valve) closes, the standing valve (SV) opens, the TV opens, and the SV closes. Ideally, at prolonged speeds, you might be able to achieve a shape resembling a rectangle. However, it becomes challenging at higher speeds, and your shape will change.

Imagine you have obtained a surface dynamometer card like this one, and I'd like to ask you to draw a pump curve. Various wave equations can be employed to eliminate unnecessary components, such as rod motion, and focus solely on the pump's area dimensions. This process results in a smooth curve known as the pump curve. Therefore, you'll have two curves: the surface dynamometer curve and the pump curve.

The pump curve doesn't display rod motion, whereas the surface dynamometer card reveals everything. Why is the dynamometer curve necessary? Well, if you possess a dynamometer card, you can determine whether your pump is experiencing fillage issues or problems with the tubing. You can glean insights into many parameters and properties of the wellbore and your pumping system from this dynamometer card. Furthermore, if you employ wave equations to approximate and eliminate the tubing and rod effects, you can obtain an idealized curve. To understand the entire pumping system comprehensively, you need to grasp both the dynamometer curve and the pump curve to evaluate the performance of your wellbore and pumping system.

F_o = fluid load on pmp

$$= A_p(\Delta p) = \frac{\pi}{4} d_p^2 \left[PDP - \boxed{PIP} \right]$$

The next thing to consider is when you have a pump that encounters a significant amount of gas. There was very little gas initially, but you start experiencing higher gas levels later. What happens then? In such a scenario, you need to use a pump-off controller. What does a pump-off controller do? Its primary task is stopping the pump or using a Variable Frequency Drive (VFD).

For instance, if you have a situation where the liquid supply is only 10 barrels per day, but you're trying to pump 20 barrels per day, there is a gap between the demand and supply. In this case, gas can start accumulating in the cylinder. When gas builds up, it becomes challenging to manage. One solution is temporarily switching off the pump, allowing the liquid column to accumulate in the wellbore. You can repeat this process: stop the pump for a certain period, let the liquid column build up, and then resume pumping.

Another approach is to keep the pump running continuously but change its speed. How do you change the speed? You can alter the V-belt, switch gears, or, in modern times, use a Variable Frequency Drive (VFD). A VFD adjusts the electrical frequency, which, in turn, changes the motor's speed. You can control the pump's Strokes Per Minute (SPM) by modifying the motor speed. For example, if you initially pump at 10 SPM, you can reduce it to 5 SPM, lowering the liquid flow rate. Slower speeds allow the liquid column to build up from the reservoir to the wellbore before pumping again.

So, you have two options for dealing with gas accumulation inside the cylinder. There are two main issues to consider. One issue is when very little fluid enters the cylinder; the other is when you create a two-phase flow. Fluid entering your pumping area can reduce pressure as the plunger moves up the cylinder. Reduced pressure means that any dissolved gas can come out. In the case of a two-phase flow or if you already have a reservoir with both gas and liquid phases, the situation changes. In such cases, you might need to employ a gas anchoring system by placing your pump below the perforations, using a gas separator or separator, or hiring a gas lock breaker or a pump-off controller mechanism.

Now, let's move on to the next topic: rod systems. There's one more topic to cover. When discussing fluid load on the pump, we often refer to it as the 'fluid load.' The formula for fluid load is as follows: Fo = Ap * ΔP = π/4 * dp^2 * (PDP - PIP). Here, PIP stands for pump intake pressure, and PDP represents the pump delivery pressure. The diameter of the plunger is denoted as dp. Some may use a capital 'P' for plunger diameter, which is also acceptable, but it's essential to maintain uniformity in the unit symbols you use throughout your work. The equation for PIP is: PIP = Cp * (1 + (hd * dFl / 40000)), where Cp is the pump constant, hd is the dead fluid load (gas-free), and PDP is the difference between PIP and ΔP. PDP can be calculated as follows: PDP = tubing pressure + (0.433 * Sgoil * h * Sn) + GFLAP.

$$PIP = C_p\left(1 + \frac{h_{D,fL}}{4000}\right) + 0.433\, SG \times GFLAP$$

$$PDP = TP + 0.433 \times SG \times h_{s,n}$$

Let me illustrate this with a diagram: Imagine a casing, tubing, barrel, and plunger. PIP is located here, while PDP is located here. GFLAP represents the gas area, indicating the portion with gas. The term 'hSn' signifies the true vertical depth (hSn). Tubing stretch (TCH) can be calculated using the formula: TCH = (Ktubing * Ltubing * Fpull). Here, Ktubing is the tubing constant, Ltubing is the tubing length, and Fpull represents the force applied. This equation provides the total tubing stretch, indicating how much elongation occurs due to the force applied to the tubing. The full downhole or plunger stroke length (S) can be determined using the formula: S = (SL – stretch rod + overtravel), where SL is the stroke length, S represents rod stretch, and 'overtravel' accounts for any additional movement beyond the stroke length.

Tubing stretch $= k_t \times L_t \times F_{pull}$

Total down hole plunger stroke length $S = SL - S_R + \text{over travel}$