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Evaluation of Sucker Rod Pump Performance for Well X in the Y Field

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ABSTRACT

Natural decline in reservoir pressure often causes oil wells to lose their natural flow capability, necessitating the implementation of artificial lift methods to maintain economic production levels. This study focuses on evaluating the performance of a Sucker Rod Pump (SRP) unit in Well X. Also known as beam pumping, the SRP is the oldest and most widely used artificial lift method for extracting oil from reservoirs with insufficient natural pressure. Well X exhibits a Productivity Index of 1.41 bpd/psi with a maximum flow rate of 574.082 bpd; therefore, an evaluation was conducted to determine the pump's volumetric efficiency. Currently, Well X has a total flow rate of 90 bfpd. A well is considered efficient if the volumetric efficiency of the installed pump exceeds 70%. If the efficiency falls below this threshold, optimization is required to achieve optimal performance. The evaluation results show a volumetric efficiency of 42.99%, indicating that the pump operation in this well is not yet efficient.

Keywords: artificial lift; sucker rod pump; productivity index; pump efficiency volumetric

I. INTRODUCTION

The Indonesian upstream oil and gas industry is currently facing a critical phase where most of its production fields have entered the mature fields category. This condition is characterized by a natural decline in reservoir pressure, causing wells to lose the energy required to flow fluids to the surface via natural flow (Hartono et al., 2014). Most oil reserves are volumetric in nature, where the primary drive mechanism is the expansion of dissolved gas as reservoir pressure decreases due to fluid production. Oil reserves will ultimately be unable to produce fluids at an economic rate unless there is a natural drive mechanism (such as an aquifer or gas cap) or a pressure maintenance mechanism (such as water or gas injection) to maintain reservoir energy. The only way to achieve high production rates from these wells is by increasing the production pressure drawdown by reducing the bottomhole pressure using artificial lift methods (Guo et al., 2007).

Artificial lift methods are applied to produce fluids from wells that are no longer productive and to increase production rates from wells that are still active. It is estimated that there are approximately two million oil wells spread across the world, of which about 50% utilize artificial lift methods (Takacs, 2015).

The purpose of artificial lift is to maintain a stable, lower bottomhole pressure so that the formation is capable of producing the expected reservoir fluids. A well may be able to do this using its natural energy, but after a long period of production, the well can only produce a fraction of the expected fluids. During this stage of the well's production cycle, and even more so after the well stops flowing, an appropriate artificial lift method must be applied to maintain the desired bottomhole pressure. Maintaining the desired bottomhole pressure is the basis for the design of any artificial lift installation; if the predetermined pressure drawdown can be maintained, the well will produce the desired fluids. This provision applies regardless of the type of lift method used (Brown, 1980). the primary objective in production activities is to achieve the maximum production rate consistent with the well's capacity to produce (Suherman et al., 2018).

Well X in Field Y is produced using a Sucker Rod Pump. The sucker rod pump is also known as Beam Pumping, which is the oldest and most commonly used artificial lift method to lift oil from reservoirs that lack sufficient natural pressure (Guo et al., 2007). This pump provides the driving energy to lift oil from the subsurface to the surface. The Sucker Rod Pump operates using a combination of surface and subsurface equipment (Jeter Rahayaan et al., 2022). A Sucker Rod Pump is a type of nodding pump that is included in the artificial lift methods used to increase production in natural flow wells (Suherman et al., 2018). The transition from natural flow to artificial lift occurs due to a decline in flow rates, which prevents the well from producing at its maximum potential (Oratmangun et al., 2022). This pump is effective for wells experiencing a decline in reservoir pressure (Nikolas et al., 2025).

II. METHODS

This research uses a quantitative method that combines theory and field data. Data collection involves the analysis and observation of field data, including both primary and secondary data.

2.1. Data

Table 1. Subsurface Data of Well X

Data	Value (ft)
Total Well Depth	2,178.58
Pump Depth, L	1,793.03
Mid-Perforation Depth	1,952.20
Dynamic Fluid Level, DFL	177.174
Static Fluid Level, SFL	0

Table 2. Production Data of Well X

Data	Value
Total Production Rate, Q	90 bbl/d
Oil Production Rate, Qo	89 bbl/d
Water Production Rate, Qw	1 bbl/d
Water Cut, WC	0.0111
Oil Specific Gravity, SGo	0.83 SG

Table 3. Pump and Well Equipment Data

Data	Value
Casing Diameter	7 in
Tubing Outer Diameter 2 7/8 (OD)	2.875 in
Tubing Inner Diameter 2 7/8 (ID)	2.441 in
Tubing Depth, H	1710 ft
Plunger Diameter	2.25 in
Rod Diameter 3/4, R1	0.535 in
Rod Diameter 7/8, R2	0.465 in
Rod Weight 3/4, M1	1.63
Rod Weight 7/8, M2	2.22
Rod Cross-Sectional Area 3/4, Ar1	0.442
Rod Cross-Sectional Area 7/8, Ar2	0.601
Tubing Internal Area 2 7/8, At	1.812 in2
Stroke Length, S	54 in
Pumping Speed, N	7 SPM

2.2. Calculation

Prior to the pump evaluation, calculations must be performed to determine the static pressure (Ps) and bottom-hole flowing pressure $\left(P_{wf}\right)$.
Determining Fluid Gradient (Gf).

$$Gf = 0.433 \times SGmix \tag{1}$$
$$Gf = 0.433 \times 0.832$$
$$Gf = 0.360\ psi/ft$$

Determining Static Pressure (Ps).

$$Ps = (Mid\ Perfo - SFL) \times Gf \tag{2}$$
$$Ps = (1{,}952.195 - 0) \times 0.360$$
$$Ps = 703.382$$

Determining Bottomhole Pressure (Pwf).

$$Pwf = (Mid\ Perfo - DFL) \times Gf \tag{3}$$
$$Pwf = (1{,}952.195 - 177.174) \times 0.360$$
$$Pwf = 639.545\ ft$$

To obtain the formation productivity of Well X, calculations were performed for the productivity index and the construction of an Inflow Performance Relationship (IPR) curve using the Vogel equation. The productivity index

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represents a well's production capacity, defined as the volume of oil produced for every unit of pressure drawdown (Puspita & Utoyo, 2016). The IPR curve is designed to identify the maximum flow rate the well can produce and the optimum flow rate, which serves as a reference for pump evaluation (Oraplawal et al., 2025). The calculation steps are as follows:
Calculating the Productivity Index for Well X.

$$PI = \frac{Q}{Ps - Pwf} \tag{4}$$

$$PI = \frac{90}{703.382 - 639.545}$$

$$PI = 1.41\ bpd/psi$$

Calculating the Qmax value.

$$Q_{max} = \frac{Q}{1 - 0.2\left(\frac{Pwf}{Ps}\right) - 0.8\left(\frac{Pwf}{Ps}\right)^2} \tag{5}$$

$$Q_{max} = \frac{90}{1 - 0.2\left(\frac{639.545}{703.382}\right) - 0.8\left(\frac{639.545}{703.382}\right)^2}$$

$$Q_{max} = 574.082\ bpd$$

Calculating the Qopt value.

$$Q_{opt} = 80\% \times Q_{max} \tag{6}$$

$$Q_{opt} = 80\% \times 574.082$$

$$Q_{opt} = 459.265\ bpd$$

Table 4. Results of Pwf Calculations Using Assumptions

Pwf	Q
703.382	0
633.043	98.742
506.435	253.331
354.504	399.553
212.702	497.363
106.351	546.222
42.54	565.458
12.762	571.847
2.552	573.659
0.255	574.04

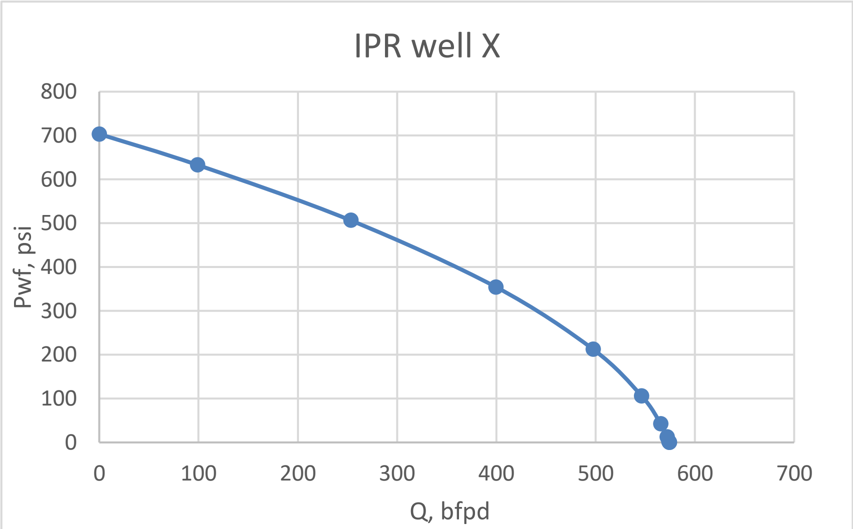

Figure 1. IPR Curve for Well X

After analyzing the IPR curve, the next stage involves evaluating the performance of the installed sucker rod pump. The steps conducted in the pump evaluation process are as follows:
Plunger Diameter, Top Rod Diameter, and Constant (K) Determination.

$$A_p = 0.25 \times \pi \times d^2 \tag{7}$$

$$A_p = 0.25 \times \pi \times 2.25^2$$

$$A_p = 3.976\ in$$

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$$A_{tr} = 0.25 \times \pi \times d^2 \tag{8}$$

$$A_{tr} = 0.25 \times \pi \times \left(\frac{3}{4}\right)^2$$

$$A_{tr} = 0.442\ in$$

$$\mathrm{K} = 0.1484 \times A_p \tag{9}$$
$$\mathrm{K} = 0.1484 \times 3.976$$
$$\mathrm{K} = 0.590$$

Rod String Weight and Fluid Weight Determination.

$$W_r = (M_1 \times L_1) + (M_2 \times L_2) \tag{10}$$

$$W_r = (1.63 \times 959.273) + (2.22 \times 833.761)$$

$$W_r = 3{,}414.564\ lb$$

$$W_f = 0.433 \times G\left(LA_p - 0.294W_r\right) \tag{11}$$
$$W_f = 0.433 \times 0.832\ (1{,}793.033 \times 3.976 - 0.294 \times 3{,}414.564)$$
$$W_f = 2{,}206.987\ lb$$

Impulse Factor Determination.

$$\alpha = \frac{S \times L^2}{70500} \tag{12}$$

$$\alpha = \frac{54 \times 7^2}{70500}$$

$$\alpha = 0.038$$

Peak Polished Rod Load (PPRL) and Minimum Polished Rod Load (MPRL) Determination.

$$PPRL = W_f + W_r(1 + \alpha) \tag{13}$$
$$PPRL = 2{,}206.987 + 3{,}414.564\ (1 + 0.038)$$
$$PPRL = 5{,}749.706\ lb$$

$$MPRL = W_r(1 - \alpha - 0.127G) \tag{14}$$
$$MPRL = 3{,}414.564\ (1 - 0.038 - 0.127 \times 0.832)$$
$$MPRL = 2{,}925.565\ lb$$

Minimum Stress and Maximum Stress Determination.

$$\sigma_{min} = \frac{MPRL}{A_{tr}} \tag{15}$$

$$\sigma_{min} = \frac{2{,}925.565}{0.442}$$

$$\sigma_{min} = 6{,}622.124\ psi$$

$$\sigma_{max} = \frac{PPRL}{A_{tr}} \tag{16}$$

$$\sigma_{max} = \frac{5{,}749.706}{0.442}$$

$$\sigma_{max} = 13{,}014.672\ psi$$

Ideal Counterbalance Effect Determination.

$$C_i = \frac{(PPRL + MPRL)}{2} \tag{17}$$

$$C_i = \frac{(5{,}749.706 + 2{,}925.565)}{2}$$

$$C_i = 4{,}337.635\ lb$$

Peak Torque Determination.

$$PT = (PPRL - C_i) \times \frac{S}{2} \tag{18}$$

$$PT = (5{,}749.706 - 4{,}337.635) \times \frac{S}{2}$$

$$PT = 38{,}125.902\ in\ lb$$

Plunger Overtravel Determination.

$$e_p = \frac{40.8 \times L^2 \times \alpha}{E} \tag{19}$$

$$e_p = \frac{40.8 \times 1{,}793.033^2 \times 0.038}{30 \times 10^6}$$

$$e_p = 0.164\ in$$

Rod Stretch Determination.

$$e_r = \frac{12 \times W_f}{E} \times \left(\frac{L_1}{A_{r1}} + \frac{L_2}{A_{r2}}\right) \tag{20}$$

$$e_r = \frac{12 \times 2{,}206.987}{30 \times 10^6} \times \left(\frac{959.273}{0.442} + \frac{833.761}{0.601}\right)$$

$$e_r = 3.141\ in$$

Tubing Stretch Determination.

$$e_t = \frac{5.20 \times G \times DFL \times A_p \times L}{E \times A_t} \tag{21}$$

$$e_t = \frac{5.20 \times 0.832 \times 177.174 \times 3{,}976 \times 1{,}793.033}{(30 \times 10^6) \times 1.812}$$

$$e_t = 0.33\ in$$

Effective Plunger Stroke Determination.

$$S_p = (S + e_p) - (e_t + e_r) \tag{22}$$

$$S_p = (54 + 0.164) - (0.33 + 3.141)$$

$$S_p = 50.693\ in$$

Pump Displacement Determination.

$$PD = K \times S_p \times N \tag{23}$$

$$PD = 0.590 \times 50.693 \times 7$$

$$PD = 209.381\ bfpd$$

Volumetric Efficiency Calculation for the Installed Pump.

$$E_v = \frac{Q}{PD} \times 100 \tag{24}$$

$$E_v = \frac{90}{209.381} \times 100$$

$$E_v = 42.99\%$$

III. RESULTS AND DISCUSSION

Well X has a total well depth of 2,178.582 ft, with a mid-perforation depth of 1,952.195 ft. The rod sizes are 3/4 in and 7/8 in, with rod weights of 1.63 lb/ft and 2.22 lb/ft, respectively, and a plunger diameter of 2.25 in.

To determine the production capacity of Well X, an Inflow Performance Relationship (IPR) curve is utilized. The IPR curve represents the correlation between the production rate and the flowing bottomhole pressure. The productivity evaluation of this well is conducted by determining the flow rates at various drawdown levels, where the calculations are based on the assumed ratio of flowing bottomhole pressure to static reservoir pressure. The maximum flow rate is calculated to identify the well's absolute open flow potential, and this well has a maximum flow rate of 574.082 BPD. Meanwhile, the optimum flow rate is calculated to determine an economically sustainable production rate for the long term, and this well has an optimum flow rate of 459.256 BPD. This well has a moderate Productivity Index (PI), as the PI value is less than 1.5, specifically 1.41 bpd/psi, indicating that the well is still producing reasonably well and remains economical, though not entirely optimal.

The plunger diameter is calculated to determine the pump's production capacity, and this well utilizes a plunger diameter of 3.976 in. The top rod diameter is calculated to verify the mechanical strength of the top rod against the applied loads; specifically, the cross-sectional area is checked to ensure that the stress remains within the material's allowable stress limits. This well has a top rod diameter value of 0.442 in.

The SRP unit at Well X has the serial number C-144-133-54, which designates a Conventional Unit with a maximum peak torque of 144,000 in-lb, a maximum polished rod load of 13,300 lb, and a maximum stroke length of 54 in. This well is currently operating with a stroke length of 54 in and a pumping speed of 7 SPM.

Based on the calculated data above, Well X is categorized as operating inefficiently, achieving a volumetric efficiency of only 42.99%. This value falls below the economic threshold of 70%, emphasizing the urgent need for design optimization. Remedial measures are required to achieve the targeted maximum production rate.

IV. CONCLUSION

Based on the analysis, Well X has a Productivity Index of 1.41 bpd/psi, indicating that the well is still producing reasonably well and remains within the economical category, although its performance has not yet reached the optimal point. The well's potential is demonstrated by a maximum production rate of 574.082 bpd. However, the calculation of the pump's volumetric efficiency recorded only 42.99%, meaning the current pump capacity is not operating efficiently as it remains below the general efficiency standard of 70%.

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