EVALUASI KINERJA ESP DN1800 UNTUK MENAIKAN PRODUKTIVITAS SUMUR MINYAK

EVALUATION OF ESP PERFORMANCE DN1800 TO INCREASE WELL PRODUCTIVITY

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Abstrak

Pemanfaatan *Electrical submersible pump* (ESP) pada metode oil lifting sangat populer karena mudah dalam hal pemasangan, sedikitnya instalasi alat di lapangan dan memiliki efisiensi yang tinggi. Untuk mencapai Q target, parameter ESP seperti jumlah stage dan RPM perlu dilakukan Analisa agar sesuai dengan grafik IPR (*Inflow Performance Relationship*). Penggunaan nodal analisis digunakan untuk menentukan hubungan antara Pwf sumur dengan head pompa. Perlu dilakukan iterasi untuk menentukan range jumlah stage agar align dengan grafik IPR. Didapat bahwa rekomendasi range stage adalah 580-600 stage pada kedalaman sumur 7684 ft dan didapat bahwa dengan 3600 RPM dan 600 stage mampu mencapai Q target. Hubungan antara jumlah stage dan nilai RPM dengan Pwf berbanding terbalik.

Kata Kunci: ESP, nodal analysis, IPR, artificial lift

Abstract

The use of the *Electrical Submersible Pump* (ESP) in the oil lifting method is very popular because it is easy to install, less required installation of tools in the field and a high efficiency. To achieve the Q target, ESP parameters such as the number of stages and RPM need to be analyzed to align with the IPR (*Inflow Performance Flow*) curve. The use of nodal analysis is used to determine the relationship between Pwf and head pump. Iteration needs to be done to determine the range of the number of stages so that it aligns with characteristics of well. It is found that the recommended range stage is 580-600 at a well depth of 7684 ft. Moreover, it is found that with 3600 RPM and 600 stages is able to reach the Q target. The relationship between the number of stages and RPM value with Pwf is inversely proportional.

Keywords: ESP, nodal analysis, IPR, artificial lift

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INTRODUCTION

Oil exploitation enforces an abundance of oil for many years in order to provide energy that has been increased annually [1], [2]. Owing to exploitation, the capacity of well production decreases due to decreasing natural pressure.

In order to supply the high demand consumption of energy the well production must reach the oil target production by doing various feasible attempts. Various research has been done to enhance oil productivity [3], [4].

Generally, well age productivity is between 10-15 years or even 40 years but that depends on the capacity of the well. There are some phases of well that have happened such as increased productivity, plate shift, well fluid injected, and well dead [5].

In the aim of oil production there are three categories: primary, secondary and tertiary to improve well productivity. Primary production uses only natural flow and artificial lift, secondary one uses pressure maintenance by using improved oil recovery (IOR), and the last uses enhanced oil recovery. The reason for classification is in age of well by starting from primary to tertiary [6].

Naturally bottom pressure of the well could over all surface losses pressure thus oil could go to the surface. But due to several causes such as: the bottom pressure drops below the surface pressure loss or the resistance of the well becomes larger enough to tackle the bottom pressure. The first cause comes from the least amount of liquid in the reservoir and the second one is owing to higher density of oil or mechanical problems. Due to these reasons, well needs artificial lift to overcome the pressure losses [5]

Artificial Lift

Generally, there are two methods for artificial lift, first gas lifting and the other one is pumping. In the simple way, gas lifting is used gas with no moving part to transport the oil. It is only an alteration of properties of fluid and a mixing between gas and oil. For pumping, another part of tools that is installed whether at downhole or surface that would help to lift the oil. The explanation will be elaborated in this section:

Gas lifting where the high-pressure gas is injected into the well from another side. This high pressure is present because of the high resistance flow of the well. In Figure 1 once gas and oil are mixed the density mixture will have lesser density than oil density itself. By reducing the density would affect the flow resistance in the well and it becomes less. So that well bottom pressure would be sufficient to lift oil[7]

Some types of flow would be used as gas lifting such as continuous flow and intermittent flow. The difference between this type is only on the flow. In the continuous flow, gas is injected continuously. For intermittent flow, gas is injected periodically and waiting until there is a slug pattern formed to be injected. There is a plunger to assist in the intermittent flow[5].

Pumping is another way to lift the oil. By definition, there is an additional instrument that would be installed whether in the surface or in the downhole in order to add the pressure to overcome pressure loss or resistance of the flow. There are three types of pump that would be used as artificial lift there are rod pumping, rod-less pumping and jet pumping [5]

Figure 1. Gas lifting [8]

Rod pumping is one of the types that utilized a string to connect the movement pump at downhole to the surface driving mechanism or simply called sucker-rod-pumping. The disadvantage of a rod pump would be hassle for deep distance intention. [5]

The second one type is rod-less pumping. This type is only utilized pumping at downhole without rod string attached and it is in favor of such a very long distance of the well. So, that is why rodless pumps are more popular rather than the first type for longer distance well [7]. As in Figure 2, it is an electrical submersible pump (ESP), one of the examples of rod-less pumping.

Figure 2. Electrical Submersible Pump (ESP)[8]

Jet pump is the only type of pump that has no movement part. The concept is converting the high pressure of flow into a large amount of kinetic energy. Therefore, after a jet pump, a high velocity is formed then it could lift the oil. [5]

Comparison of Artificial Lift

Comparison between two methods that would be useful for this research since it is very vital in selecting the appropriate method. It is shown in Figure 3 that Gas lift has a wide range both at lifting depth and flow rate. Different from gas lift, the jet pump is in the smallest range and ESP is in the middle range. From Figure 3. It is concluded that ESP is still a feasible method for deep distance of well even though gas lift is over ESP in the range but ESP is simpler and less space installation. [3]

Figure 3. Comparison of Artificial Lift [5]

Inflow Performance Relationship (IPR)

Inflow Performance Relationship (IPR) is the relation between flowrate and pressure of a well. This relation is very important to predict the characteristics of well. The graph was depicted by Vogel [5] formulation in the equation (1) and it is shown in Figure 4.

$$\frac{q}{q_{max}} = 1 - 0.8 \left(\frac{p_{wf}}{p_R} \right)^2 - 0.2 \frac{p_{wf}}{p_R} \quad (1)$$

p_{wf} is denoted as pressure well formation (Psi), p_R is pressure reservoir in Psi, q is flowrate in BPD and q_{max} is the maximum flowrate. Figure 4 shows the relation between pressure and flowrate. Axial x and y ordinate is in fraction form and it shows flowrate and Pwf respectively. The maximal pressure is known as Static Well Pressure (SWP) where the pressure is obtained when a well is not operated or a valve in the Christmas tree is closed[7].

Figure 4. Inflow Performance Relationship (IPR)[5]

To get a prediction of the characteristic of a well, equation (1) is used. This information is very important for engineers to evaluate whether the method of artificial lift is feasible or not.

RESEARCH METHODOLOGY

In this research there are several steps conducted including literature review, formulate Pwr using nodal analysis, draw IPR of well, calculate pressure loss in the tube and evaluate the performance of ESP DN1800 as shown in the Figure 5.

Figure 5. Research methodology

Nodal Analysis

In Figure 5, nodal analysis is a method that is used to evaluate pressure from one node to another node. The node represents a point or apparatus or tools that would be analyzed in the term of pressure conservation. The nodal analysis in this research illustrates in Figure 6.

Figure 6. Nodal analysis in this research[5]

In the Figure 6, node 2 represents Flow Bottom Head Pressure (FBHP) that is same as Pwf, Well Head Pressure (WHP) is same as Pwh at node 5, Pressure Intake Pump (PIP) is at node 3, and Pressure discharge (Pd) is at node 4.

From nodal analysis it is evaluated that Pwf is formulated in the following:

$$P_{wf} - (L_2 - L_3)\rho_{mix}g = PIP \quad (2)$$

ρ_{mix} is density fluid mixture, for pressure discharge pump:

$$P_d - \Delta P_{friction} - L_3\rho_{mix}g = P_{wh} \quad (3)$$

And the nodal analysis for ΔP_{pump} :

$$P_d - PIP = \Delta P_{pump} \quad (4)$$

It is denoted that L_2 is depth perforation, L_3 is depth setting pump and $\Delta P_{friction}$ is the pressure loss in tubing. Nodal analysis uses the pressure at lower node that is bigger than upper node, but only one exception since pump is giving the energy to lift oil then $P_d > PIP$. By substitution equation (2,3,4), equation (5) is described as it follows:

$$P_{wf} = L_2\rho_{mix}g + \Delta P_{friction} - \Delta P_{pump} + P_{wh} \quad (5)$$

In the head form, equation (5) is divided by $\rho_{mix}g$ then,

$$\Delta H_{pump} = L_2 + \Delta H_{friction} - 2.31 \frac{(P_{wf} - P_{wh})}{S_{gmix}} \quad (6)$$

ΔH_{pump} is head required for ESP, S_{gmix} is specific gravity of mixture fluid and it is obtained from this equation in the following:

$$S_{gmix} = (W_c S_{gwater}) + (1 - W_c) S_{g oil} \quad (7)$$

Calculate Head Loss Friction

From equation (6), it needs head loss by friction in the tube to get the head required for ESP. To find friction loss in the tube, it uses Hazen-William graph [9] as shown in Figure 7 which shows the head loss for tubing per 1000 ft. It is very useful by only finding flowrate and tubing case size, head loss could be acquired.

Figure 7. Hazen-William Graph for Tubing Head Loss

Net Positive Suction Head

Net Positive Suction Head (NPSH) shows the performance of the pump in this case DN1800 ESP and it is shown in Figure 8. It shows relation between head/stage and capacity flowrate (BPD).

Figure 8. NPSH ESP DN1800

Head required for ESP is the total head of all stages. This data is very important and as key design to find the number of estimations of stage. To calculate the number of stages, it can be used equation (8) as it follows:

$$N = \frac{\Delta H_{pump}}{h} \quad (8)$$

Where N is the number of stages and h is head/stage obtained from Figure 8. It is underlined in selection of h that the range selection is in flowrate recommendation (bold line).

RESULTS AND DISCUSSION

To begin with results, this discussion elaborates the characteristic of well that uses equation (1). In the Figure 9. it shows the relation between Pwf and flowrate of well. There are Q target (target flowrate) and Q now (existing flowrate). The existing flowrate is far enough from target flowrate which is 80% of maximum flowrate. ESP is responsible to reach Q target and Pwf align with IPR. ESP evaluation will be explained later on.

Figure 9. IPR Well

The graph is plotted by using several properties of the well that is tabulated in Table 1. This information is not only used to plot IPR but also to calculate required head pump and mix specific gravity in the equation (6) (7) respectively.

Table 1. Well Data Collection

Q_{fluid} (Q now)	1134 BFPD		Tubing Pressure (Pwh)	575.61 Psi
SG Oil	0.87		Reservoir Pressure (Pr)	1610 Psi
SG Water	1.05		Flow Bottom Head Pressure (Pwf)	1126.48 Psi
Water Cut	78 %		pump setting depth (L3)	6800 ft
Oil Cut	22 %		bottom perforation depth (L2)	7684 ft

After plotting a characteristic IPR line in the Figure 9., formulate nodal analysis will be conducted. Nodal analysis has been done on the previous section that illustrates clearly in Figure 6. By seeing Equation (6), $\Delta H_{friction}$ and S_{gmix} are required. Finding mix specific gravity could be done by evaluating Equation (7) and using data from Table 1, the result is 1.0104.

Calculation of head loss friction in tubing is obtained by using Hazen-William graph and data in Table 2. After matching the data in Table 2 and flowrate target 1936.11 BPD with Hazen-William graph, the result of head friction loss in the tube is 35 Ft/1000 Ft. The depth that is used for tubing losses is L3 (6800Ft). So, total head loss is 238 Ft or 1236.648 Psi.

Table 2. Tubing Data

Length (Ft)	6800
OD Tubing (Inch)	2 7/8
ID Casing (Inch)	2.441

Once head loss friction is obtained, the required head pump could be evaluated by using equation (6) and the result is 6631.65 Ft. In other words, a pump or ESP has to provide head as much as 6631.65 Ft. To convert frequency of ESP to RPM, it is simple just multiply it by 60 and the results are tabulated in Table 3.

Table 3. Frequency conversion to RPM

Freq (Hz)	RPM
50	3000
55	3300
60	3600
65	3900
70	4200

Finding the number stage of ESP is quite tricky, from NPSH DN 1800 in range recommendation flowrate at 3000 RPM, the maximum stage is 884 stages and the minimum one is 402 stages. These ranges are based on estimation to find maximum and minimum number of stages using Equation (8). This problem cannot be solved until doing iteration by taking a number of estimation stages in the range maximum and minimum stage and doing evaluation of ESP at once.

Evaluation of ESP is taking into consideration by plotting Pwf ESP at the same graphic as IPR well. The criteria that ESP evaluation is success when Pwf ESP line (equation 5) intersect with IPR well. In the Figure 10. it shows evaluation ESP DN 1800 at 3000 RPM and it uses different estimation of stages. The relation, when increasing number of stages, shows decreasing of Pwf range. Green line intersects the IPR line and red line shows otherwise. As matter of fact that ESP existing at 3000RPM has Qnow flowrate in the field. Therefore, the number of stages used in the field is 580 stages. If the number of stages is increased up to maximum number, the purple line cannot intersect Qtarget. Purple line has negative range of Pwf, this condition cannot be satisfied which means that ΔP_{pump} is over than Pwf in the Equation (5). In other words, ΔP_{pump} is overpressure and it is dangerous.

Increasing stages number is not only a solution to reach Q target, increasing RPM would be another option. It shows in Figure 11, that at 3600 RPM could reach Qtarget at 600 stages. This result is acquired with iteration at 3600 RPM and varying the number stage from 550-600 to find maximum stages. It is recommended that the range performance of NPSH DN 1800, the number of stages between 550 and 600 should handle the characteristic well. This conclusion arises when the line at 4200 RPM and 550 stage is intersected with the maximum flowrate of the IPR line. If the stage is more than 550 at 4200 RPM shows otherwise. Furthermore, In this figure also describes the relation between RPM and Pwf, it is clearly shown when RPM increases, Pwf range will decrease.

Figure 10. Evaluation ESP with Different N Stages

Figure 11. Evaluation ESP with Different RPM

CONCLUSION

Evaluation of performance ESP DN 1800 has been done to seek parameters, frequency and number of stages. It is clearly shown that the relation between RPM and Pwf is opposite and this relation is the same as number stages. The feasible value of parameters that could reach Qtarget in this research are 3600 RPM and 600 stages. Although this research has its own limitations such as validation, this research is very important to predict the parameter of ESP when Q now is far from Q target. The number of stages and RPM are tuning parameters that could be varied in order to reach Q target. Recommendations for the number of stages especially for this well characteristic are between 550 and 600.

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