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Applications of line-pack model of gas flow in intermittent gas lift injection line

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ABSTRACT

Intermittent gas lift is one of injection techniques for mature wells with low-productivity. This technique has two periods i.e. shut-in and production periods. During shut-in period the choke is closed, and the gas flows from the compressor into the gas-line. Furthermore, production period takes place when the choke is open to allow the gas flows into the tubing-casing. This process is similar to line-pack and line-draft in transient gas flow. It is known that the upstream choke pressure should be high enough to lift the oil. Hence, it is very important to control the shut-in period. In this paper, a line-pack model for an intermittent gas lift is constructed. The model is used to predict high-pressure performance at the upstream choke. Moreover, the model is compared with field data from literature. The effect of opened-closed choke to the pressure and the gas rate is analyzed. Sensitivity analysis with respect to gas-line length, gas rate, discharge pressure, and duration of shut-in are shown. The results show that the pressure at the upstream choke can be estimated as well as the duration of shut-in which are critical in increasing the pressure. This model is important for avoiding production operation failure.

1. Introduction

The ability of reservoirs to produce oil in the long term will naturally decrease as a function of time. This will affect the pressure around the bottom and the capability to transport oil. Therefore, the production of oil will decrease. An artificial lift method can be used to solve this problem. One of the artificial lift methods is called the gas lift method. The gas lift method includes both a continuous gas lift method and an intermittent gas lift method (Brown and Beggs, 1980).

The continuous method uses gas injection with a steady-state flow to lift oil from the bottom of the tubing to the surface (Guo et al., 2007). The intermittent gas lift method uses gas injections at regular intervals (Brown and Beggs, 1980). Intermittent gas lift operations are showed in Fig. 1. Intermittent gas lift operation consist of surface and subsurface facilities. Systems of surface facilities are compressor, gas-line, choke (motor valve), production-line, and separator. Subsurface facilities are unloading valve, packer, gas lift valve, and standing valve.

In the intermittent gas lift method, the high-pressure of gas is injected from the surface into the tubing by a motor valve (choke). Then, the gas is used to lift the oil to the separator. The process of injection occurs intermittently. Two periods are used in this method, i.e., a production period and a shut-in period. During the production period, i.e. when oil is produced, gas is flowed from the compressor to the gas-line and then enters into the tubing-casing through choke. The high-pressure gas opens the gas lift valve and enters the tubing to propel oil upwards.

Gas is used to propel the oil to produce in piston form (Brown and Beggs, 1980). The process of injection continues until the oil is produced at the production-line. After the oil reaches the production-line, the gas injection is stopped (shut-in period). During the shut-in period, the reservoir is flowing oil through the tubing and gas from the compressor is also flowing through the gas-line with a closed choke. Gas will then be accumulated in the gas-line until the choke is opened. This phenomenon can be seen in Fig. 1 and can be modeled as the line-packing phenomena of gas injection flow during shut-in conditions.

There are many studies that have examined continuous gas lift, gas flow, and intermittent gas lift. Saepudin et al. (2007) studied the gas lift performance curve (GLPC) and showed the existence and uniqueness of GLPC. Saepudin et al. (2009) developed an optimization model of dual gas lift to derive the optimal allocation of gas injection. Ghaedi et al. (2013) studied about optimization of gas allocation in the gas lift. Ghaedi et al. (2013) used a hybrid genetic algorithm to find optimum amount of gas for a group of wells with gas lift technique. Alive and Jamalbayov (2015) formulated a mathematical model of gas-liquid mixture in the gas-lift method and the model was used to study the dynamic process of

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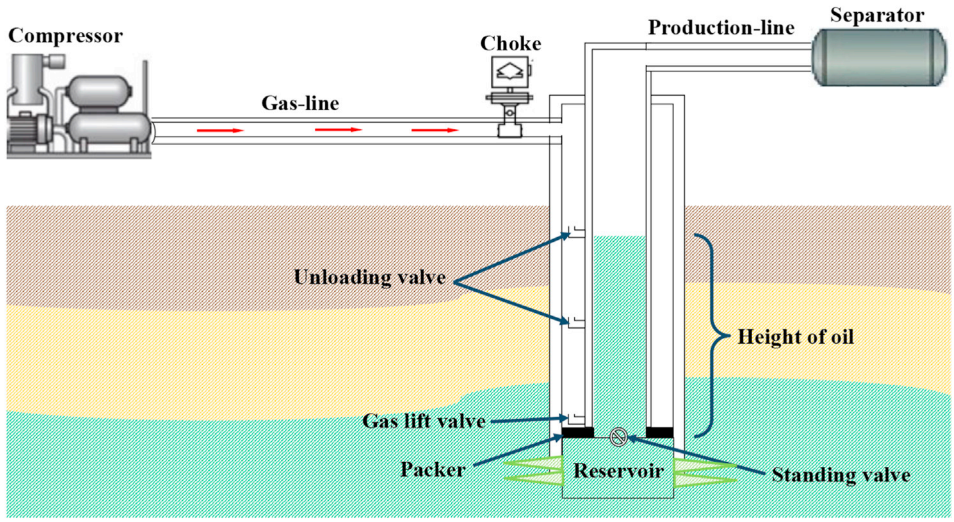

Fig. 1. Intermittent gas lift operation.

the well-reservoir system. Shao et al. (2016) developed model of gas-lift system that referred to 'plastic bag model'. Shao's model studied the behaviors of the gas-lift method.

Studies on gas flow in the pipeline and flow line were completed by Chebouba (2015), Kessal (2000), Kessal et al. (2014), Adewumi and Zhou (1995), Zhou and Adewumi (1996, 1998). Chebouba (2015) worked on a transient model of gas flow in the pipeline to minimize the cost of energy. Kessal (2000) presented simplified models of transient gas flow. Kessal et al. (2014) developed a numerical method to solve the transient model of gas flow in the pipeline. Adewumi and Zhou (1995) presented some examples of gas flow models in pipelines. Zhou and Adewumi (1998) solved the network of gas flow using a linear theory method.

The study of intermittent gas lift was conducted through experiments and modeling. Brown and Jessen (1962) calculated the average bottom pressure and the stabilization time of the pressure. Brill (1967) presented an experimental model of fall back correlation in an experimental well with a depth of 457.20 *m*. Lara and Bordalo (2013) developed a physical simulator for two artificial lift methods i.e. an intermittent gas lift method and zadson pneumatic pump method.

The modeling of intermittent gas lift has been conducted by many researchers. Liao (1991) developed a mechanistic intermittent gas lift model. In 2001, Santos et al. (2001) expanded Liao's model for use in other artificial lift methods such as gas lift with a chamber and plunger. Caicedo (2001) studied a model to estimate an inflow performance relationship (IPR). A mathematical study of intermittent gas lift was extended by Ayatollahi et al. (2004) to study the oil field in the Aghajari. A new mechanistic model of intermittent gas lift was presented by Filho and Bordalo (2005). Filho and Bordalo (2005) also developed a scheme of simulation with sequential and simultaneous stages. A model to estimate the height of the column fluid was formulated by Sandoval et al. (2005). The study of intermittent gas lift also performed by Hai et al. (2007). His study discussed the effect of medium thermo-physical and studied the intermittent gas lift with both experiment and modeling.

Bordalo and Filho (2007) designed a model of inverted intermittent gas lift (IGL-I). The IGL-I method is one of the intermittent gas lift variants. Bello et al. (2011) presented a model of plunger-assisted intermittent gas lift. Bello's model is illustrated with a numerical method. Pestana et al. (2013) further extended the intermittent gas lift model with a throttling flow pattern in the gas lift valve, a two-phase flow in the flow line production, and the dynamics of the pressure in the upstream choke throughout gas injection. Pestana's model also considered the pressure loss in the gas-line that connects the compressor with the choke. Abouie (2015) elaborated two model of the gas lift, i.e., steady state single well gas lift model and transient single well gas lift model. Abouie (2015) implemented his model to simulator (UTWELL). Tasmi et al. (2015) simplified Liao's model with assumptions the film thickness is constant. It analyzed by Tasmi et al. (2016) through a mathematical approach.

Except Pestana's model, most of the previous intermittent models assumed that the pressure of gas in the upstream choke was equal to the pressure in the compressor or pressure of gas injection is given. This is not consistent with the physical phenomenon, because gas is flowing to the gas-line from the compressor and the pressure of gas in the choke increase when the choke is closed. Pestana et al. (2013) applied Weymouth correlation (Menon, 2005) and mass conservation in the gas-line.

In this research, model is developed to consider the line-pack phenomenon and line-draf phenomenon in the gas-line. The mathematical model has some boundary conditions that corresponded to its physical phenomenon. The aim of this research is to estimate the high-pressure in the upstream choke and to analyze the dynamic of gas in the gas-line, so that the result of this research can be used to develop a design of intermittent gas lifts, compressors, and gas-lines.

2. Gas injection line model for intermittent gas lift

2.1. Assumptions of the model

Here the mathematical model for intermittent gas lift injection in the pipeline is developed under the following assumptions:

1. An isothermal condition.
2. The gas injection in the form of dry gas.
3. Unchanged gas phase (no formed condensate).
4. One compressor is used to supply several intermittent gas lift wells. If one of the intermittent gas lift wells is not active, then gas flows to other active wells.

2.2. The gas-line model

Model of gas flow in gas-line were developed based on the conservation of mass and momentum. The model of gas flow for mass conservation is:

$$\frac{\partial \rho_g}{\partial t} + \frac{\partial m}{\partial x} = 0. \tag{1}$$

The model of gas flow for momentum conservation in the gas-line with elevation is given by: