Petroleum 2 (2016) 408–414

Contents lists available at ScienceDirect

Petroleum

journal homepage: www.keaipublishing.com/en/journals/petlm

Original Article

A novel model for predicting the temperature profile in gas lift wells

Mohammad Reza Mahdiani, Ehsan Khamehchi*

Faculty of Petroleum Engineering, Amirkabir University of Technology (Tehran Polytechnic), Hafez Avenue, Tehran, Iran

ARTICLE INFO

Article history:
Received 15 March 2016
Accepted 23 August 2016

Keywords:
Temperature profile
Gas lift
Heat balance
Modeling

ABSTRACT

One of the most common methods for calculating the production oil rate in a gas lift well is nodal analysis. This manner is an accurate one, but unfortunately it is very time consuming and slow. In some modern studies in petroleum engineering such as close loop control of the wells this slowness makes it impossible to have an online optimization. In fact, before the end of the optimization the input parameters have changed. Thus having a faster model is necessary specially in some of the new studies. One of the sources of slowness of the nodal analysis is the temperature profile estimation of the wells. There are two general approaches for temperature profile estimation, some like heat balance are accurate but slow. Others, similar to linear profile assumption are fast but inaccurate and usually are not used commonly. Here, as a new approach, a combination model of heat balance and linear temperature profile estimation has represented which makes the nodal analysis three times faster and it is as accurate as heat balance calculations. To create this, two points (gas injection point and end of tubing) are selected, then using heat balance equations the temperature of those two points are calculated. In normal nodal analysis the temperature of each wanted point in the well is estimated by heat balance and it is the source of slowness but here just two points are calculated using those complex equations. It seems that between these points assuming a linear temperature profile is reasonable because the parameters of the well and production such as physical tubing, and casing shape and properties and gas oil ratio are constants. But of course, it still has some deviation from the complete method of heat balance which using regression and assigning a coefficient to the model even this much of the deviation could be overcame. Finally, the model was tested in various wells and it was compared with the normal nodal analysis with complete heat balance models. Results showed that the new model is as accurate as normal heat balance but three times faster.

1. Introduction

As reservoir pressure declines, oil rate production decreases and there is a need to use artificial lift methods to increase the oil rate production. One of the artificial lift methods is gas lift. In this method, gas is injected in a point in the tubing, it solves in oil and decreases the average density of the oil column and thus increases oil rate production [1].

In this operation, for estimating the performance of the gas lift, there is a need to calculate the production oil rate before injecting the gas. For this purpose, the nodal analysis method is used. In this method, well length is divided to sections with a length of about 100 or 150 ft. Then a flow rate is assumed and with respect to that, the fluid properties are calculated in average pressure and the temperature of the section and are assumed to be fixed in the whole section. Afterwards, the pressure loss in each section is calculated (these calculations are iterative ones, because pressure loss depends on average fluid properties and fluid properties depend on average pressure and temperature

* Corresponding author.
E-mail address: khamehchi@aut.ac.ir (E. Khamehchi).
Peer review under responsibility of Southwest Petroleum University.

Production and Hosting by Elsevier on behalf of KeAi

http://dx.doi.org/10.1016/j.petlm.2016.08.005

and thus pressure loss). Now that the pressure of the end of the section is known, this pressure is the pressure of the top node of the next section. These calculations are repeated for the next section once more. Continuing this and starting from the wellhead as a known node, and proceeding to calculating the pressure loss of each section, well bottom pressure is calculated. This operation is repeated for different oil rates and then production oil rate vs bottom hole pressure is plotted in the same graph with inflow performance. Their common point gives the bottom hole pressure and its corresponding oil rate. The bottom hole pressure and its corresponding oil rate of the well are found. It is clear that the fixed wellhead pressure and reservoir and well properties lead to a unique solution for the problem [2]. In addition to nodal analysis some other modeling such as genetic programming [3] and simulated annealing modeling [4,5] can be used to predict the temperature profile. But in this paper they are not discussed.

Calculating the well temperature profile in nodal analysis is of great significance and usually one of the sources of the slowness of the nodal analysis. Since the nodal analysis is a repetitious method, it is necessary that the calculation of the temperature profile be repeated over and over. As a result, it has a great effect on the speed of the nodal analysis. Thus, if we can increase the speed of the temperature profile estimation, we have to speed up the entire nodal analysis.

Different researchers have studied the methods of temperature estimation in each section of the wells. In 1959, Kirkpatrick [6] suggested a linear temperature profile between wellhead and reservoir, a fast but inaccurate method. In 1962, Ramey [7] assumed a zero well diameter and based on that introduced an equation that did not work for the deep well, high production rates and new completed wells [2–4,7–10]. In 1991, Sagar [8] extended the Ramey method and in 1992 Alves [11] introduced a method for surface pipes. Also in 1992, Farshad [11] used a neural network for building a model. It is clear that Farshad's method is based on a limited amount of experimental data and cannot simply be generalized. In 1996, Hasan-Kabir [12] represented a mechanistic model to predict the temperature profile in a gas lifted well. Their model is one of the rare models that is designed specifically for gas lift wells, with good estimation but having the problem of slowness. In 2005, Cazarez–Candia [13] represented a time-dependent homogeneous mathematical model to predict the temperature distribution in oil wells. In his model, he considered a two phase flow for the well. In 2009, Espinosa–Paredesa [14] used a strategy, based on proportional-integral (PI) feedback control to estimate the temperature profile. In 2011, Lindegerg [15] studied the temperature profile in a CO_2 injection well, taking into account the phase changes, adiabatic heating and thermal exchange with the surrounding rock. In addition, in this year Hamedi [16] introduced a numerical method for estimating temperature profile in the gas lift wells. In 2012, Kabir [17] studied the heat transfer coefficient, and the joule Thomson effect in a steady flow and unsteady temperature profile. In 2013, Duan [18] predicted the temperature profile in a waxy oil-gas pipe flow and he considered the different parameters and used the heat balance in his model. In 2014, Cheng [19] represented a model for distribution of thermal properties and oil saturations in steam injection wells. He involved the temperature logs in his studies.

As mentioned earlier, all the above models are good in natural flow but not in gas lift operation except Hasan Kabir which is good for gas lift wells but is very slow. The Hasan-Kabir model is based on heat balance. This model has been created based on fluid, tubing, annulus and ground heat balance and heat transfer and for all of them a heat transfer coefficient is proposed. As previously mentioned, this model is an accurate one, but it is very slow and time consuming especially in optimization problems in which there is a need to run the model many times. Takacs [20] suggest the Heat balance model for the gas lift temperature profile modeling as the best method. However, due to this model's slowness, some softwares (such as vfpi in Eclipse) use a linear temperature profile which is much faster but clearly not as accurate.

Now it is clear that if we modify the temperature profile estimation of the nodal analysis in a way that is as fast as the linear method and as accurate as the Heat balance model, it is of great help. Here the method of Heat balance model and the linear method are combined in a way that causes a new model as fast as the linear one and as accurate as the Heat balance model. Then it has been tested to show its performance.

2. New temperature profile modeling

As previously mentioned, one of the models in temperature profile modeling is the linear profile method. This method was not good for gas lift because the heat transfer coefficient above the injection point (with annulus filled with a gas) and below that (with annulus filled with a liquid) is different. The diameter of the oil production tube at the end of tubing also changes. Thus, the well has three different parts, from well head to injection point, from injection point to end of tubing and from the end of tubing to the well bottom. These parts are different in the inner diameter and the gas oil ratio and also heat transfer coefficient, but in each section the inner diameter is constant and fluid properties change continuously without any sudden change. Thus a linear temperature profile can be assumed between them. It is usual to use a linear temperature gradient assumption in homogenous cases such as the temperature profile in earth layers without any well, or even the temperature profile in a well with natural flow [21–23]. Thus it seems that in our case assuming a linear profile between the proposed points is reasonable. Afterward using statistical analysis, the reasonability of this assumption will be discussed and if needed the model will be improved by some other parameters or assumptions.

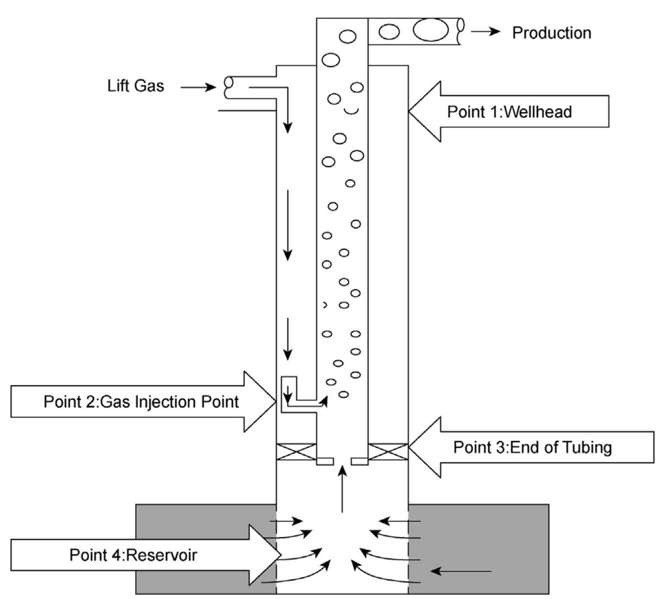

Fig. 1. Considered points in the new model of this paper (described points in wide arrows).