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A new correlation for prediction of sub-critical two-phase flow pressure drop through large-sized wellhead chokes

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ABSTRACT

Unacceptable errors resulted from utilizing the current correlations for investigating the behavior of sub-critical two-phase flow regime through wellhead chokes of south Iranian gas condensate reservoirs led us toward establishing a new Gilbert-type correlation capable of fitting the production data with minimum errors. The proposed model, which is a modification of Nasriani and Kalantariasl model, is able to predict the high flow rates of gas condensate wells under sub-critical conditions particularly in case of large choke sizes. In order to validate the new correlation, Genetic Algorithm and non-linear regression analysis methods are implemented to sixty seven production datasets of fifteen wells with large wellhead choke sizes (40/64–192/64 inch) gathered from 10 different fields. Then the proposed correlation in addition to two other models (1.Osman and Dokla 2. Nasriani and Kalantariasl) are conducted to each choke size to investigate the applicability of the new formula in comparison with the existing ones. Moreover, in order to evaluate the new model in other field data, 39 data points gathered from gas-condensate wells of Fars province of Iran are exposed to the proposed model, and the two other models. Finally, the main form of the new correlation is applied to dataset of each choke size.

The results indicate that the non-linear regression technique is more accurate than Genetic algorithm in fitting the data to the proposed method. Furthermore, the new correlation has the minimum errors in comparison to other methods in both investigated areas. Finally, according to statistical error analysis for each choke size, the ability of the proposed correlation to predict gas flow rates of fluids passing through the wellhead chokes of gas-condensate wells under sub-critical conditions is found to be highly improved when applied to individual choke sizes.

1. Introduction

Gas condensate reservoir is a particular kind of reservoir which has a behavior mediating between that of gas and volatile oil reservoirs. It contains low density liquid hydrocarbons which present as gaseous components in the raw natural gas and condense out of gas when the pressure is lowered below the dew point pressure of hydrocarbons. Due to changes in temperature and pressure, these types of reservoir are bound to instability of flow regime, fluctuation and phase change which may lead to liquid holdup and phase separation. Therefore, multiphase flow is common in gas condensate reservoirs.

The flow rate of well is the most significant parameter for characterization of a reservoir and estimation of its behavior. Wellhead chokes (a configuration which an elbow is installed exactly upstream of chokes) normally are used in wells as controlling agents to adjust the flow rate and sustain adequate back pressure to avoid sand issues and water/gas coning. Therefore, estimation of choke performance by implementation and optimization of a relation between size of chokes and wellhead flow rates is only possible through a precise modeling and selection of an optimum choke size.

Based on flow regime, the fluid flow through the choke can be characterized as either critical or sub-critical (sonic or subsonic, respectively). When Mach number is equal or more than unity (When the flow velocity is equal or greater than sonic velocity), any pressure disturbance wave from downstream cannot spread through upstream and mass flow rate reaches a maximum amount which only depends upon upstream conditions. This kind of flow is known as critical flow. Accordingly, to avoid any perturbation of

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Table 1
Different parameter ranges of south Iranian field data.

Parameters	S (1/64inch)	LGR (bbl/MMscf)	Q_g (MMscf/D)	P_u (psia)	P_d (psia)	ΔP (psia)	T_f (°F)
Minimum	40	0.688	11.3	1131	824.84	14.5	109
Maximum	192	32.215	113	4452	3045.82	1407	211

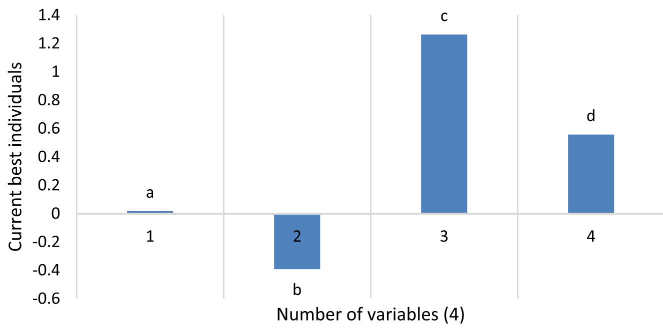

Fig. 1. Derivation of the new correlation constants by Genetic Algorithm.

surface equipment, most chokes are usually managed to work in critical flow region. In contrast, the sub-critical flow is described as the flow which its highest possible flow rate is less than sonic velocity. In this case, the mass flow rate is a function of pressure drop across the choke and any downstream disturbance is able to influence the upstream region.

Due to difficulty of estimating gas and sound velocities in the field (Nejatian et al., 2014), usually in literature, the value of 0.5 for downstream to upstream pressure ratio of chokes ($P_d/P_u = 0.5$) has been selected as the boundary between critical and subcritical flow regimes. The flow which has a P_d/P_u less than 0.5 is considered to be a sub-critical flow and the one with the ratio greater than 0.5 is considered to be a critical flow (Omana et al., 1969; Nasriani and Kalantariasl, 2011).

Empirical and Analytical methods are two categories of multiphase flow estimation approaches across the chokes. Tangren et al. (1949) were the first researchers to implement analytical investigation on two-phase flow regime across limitations of chokes. However, their method is only valid where the liquid is the continuous phase. Ros (1960) followed the Tangren et al. (1949) method and converted it into a model where gas is considered to be the continuous phase. Ashford and Pierce (1975) extended Ros (1960) model and derived a correlation to estimate the critical flow rates. However, they assessed that uncertainty is introduced in their correlation due to difficulty of determining the downstream pressure accurately (Rahimzadeh and Mohammadmoradi, 2014). An extension was implemented to Ashford and Pierce (1975) theoretical model by Sachdeva et al. (1986) for a choke placed in a direct horizontal pipe section. They derived two different correlations, one for predicting critical pressure ratio and the other for making a distinction between sonic and subsonic flow.

Brill and Beggs (1984) combined Bernoulli and continuity equations to develop a formula for calculation of sub-critical flow rates. This purely theoretical model (which is called Mechanistic model) is widely used by the industry with a proven accuracy. In another theory-based study, Perkins (1993) derived a theoretical multiphase equation based on mass, momentum and energy balance for description of isentropic flow across chokes. It is worth mentioning that some theoretical models established by Fortunati (1972), Ashford and Pierce (1975), Pilehvari (1981), Surbey et al. (1989), Sachdeva et al. (1986), and Perkins (1993) are applicable for both critical and sub-critical conditions (Nasriani and Kalantariasl, 2011; Rahimzadeh and Mohammadmoradi, 2014).

Gilbert (1954) derived the earliest empirical relation between choke size and surface flow rate by utilizing 268 production datasets from Ten Section Kern County Oil Fields of California. For derivation of his correlation, Gilbert assumed that the flow passing through an edge knife choke is critical and assessed that the correlation is valid when the upstream pressure of the choke is at least 70% higher than the downstream pressure. Gilbert's formula has the following form (Gilbert, 1954):

$$P_{wh} = \frac{cQR_{GL}^{a}}{S^{b}} \tag{1}$$

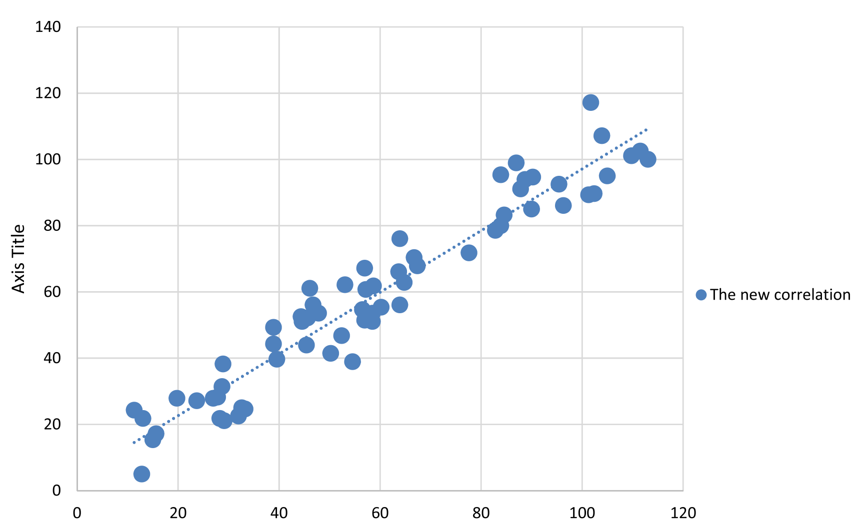

Fig. 2. Comparison of real and predicted gas flow for all data points by Genetic Algorithm.