

# Improved Rate Decline Prediction Formula Considering the Length of Hydraulic Fractures in a Jilin Field, China

Yanlong Yu<sup>1</sup>, Zhangxin Chen<sup>1</sup>, Jinze Xu<sup>1\*</sup> and Jinghong Hu<sup>2</sup>

1. University of Calgary

2. China University of Geosciences (Beijing)

\*Corresponding Author: Jinze Xu (jinz Xu@ucalgary.ca)

## Summary

In a tight oil reservoir, a rate decline prediction formula is the most common method to forecast a production rate, and hydraulic fracturing is one of the most effective treatments to enhance oil recovery. A relationship is found between parameters of a rate decline prediction formula and fracture geometry parameters by employing reservoir simulation based on the data from a Jilin Field. This relationship is used to improve the rate decline prediction formula and able to provide further assistance to determine an oil rate in a more convenient and efficient way.

## Introduction

In the 21<sup>st</sup> century, tight oil is one of the unconventional oil resources which are well exploited in North America, Asian and other regions. It brings considerable production and profits for people and also has a significant influence on the energy structure of economics. There are three reservoir rock types in tight oil reservoirs: tight sandstone, tight limestone and carbonate rocks. Low permeability and low porosity are the two most significant petrophysical characteristics of a tight oil reservoir; the tight rock owns a pore throat with a nano or micro scale, thus its permeability is extremely small, and its matrix permeability is less than  $2 \times 10^{-3} \mu\text{m}^2$ . Due to these characteristics, oil in tight oil reservoirs is difficult to reach a wellbore, which leads to low economic benefits.

To improve production, hydraulic fracturing is an efficient treatment to be applied in a tight oil field. The reason for choosing a horizontal well is to make the contact area larger between a wellbore and a reservoir. After a well is drilled, hydraulic fracturing is used to create some stimulation that improves the permeability around the wellbore. During the hydraulic fracturing, a fluid is pumped into the reservoir to generate new fractures under a high level of pressure so oil is able to flow to the wellbore through new pathways. Hydraulic fracturing exhibits good performance to overcome the issue of low permeability in tight oil reservoirs.

China has a huge number of tight oil reservoirs. For instance, in Jilin Oilfield, the average permeability of a tight oil reservoir is 0.1 md and the average porosity is 8%. The production rate of a well cannot remain stable for a long time (Zhao, 2011). Hence it is necessary to apply technical ways to achieve optimized production in an oilfield. Horizontal wells with hydraulic fracturing are great tools to tackle the low production problem for Jilin Oilfield. This paper analyzes the parameters of a transient empirical rate formula based on reservoir simulation after a hydraulic fracturing process, which aims to improve the production performance and provide certain references for future exploitation and optimization in tight oil reservoirs in Jilin Oilfield, China.

## Theory and Method

A CMG (Computer Modelling Group) model is built based on the field data collected from Jilin Oilfield, and two variable parameters which are the horizontal fracture half length and vertical half length are set to run to obtain production data under different conditions. The fracture length variables have influence on oil production data, which can be obtained from simulation results. Analyzing a correlation between these

variables can improve a rate decline prediction formula. This study provides a reference for field engineering to accelerate the decision-making and shrink the time of process designing, which has costed a plenty of time in the past.

### Examples

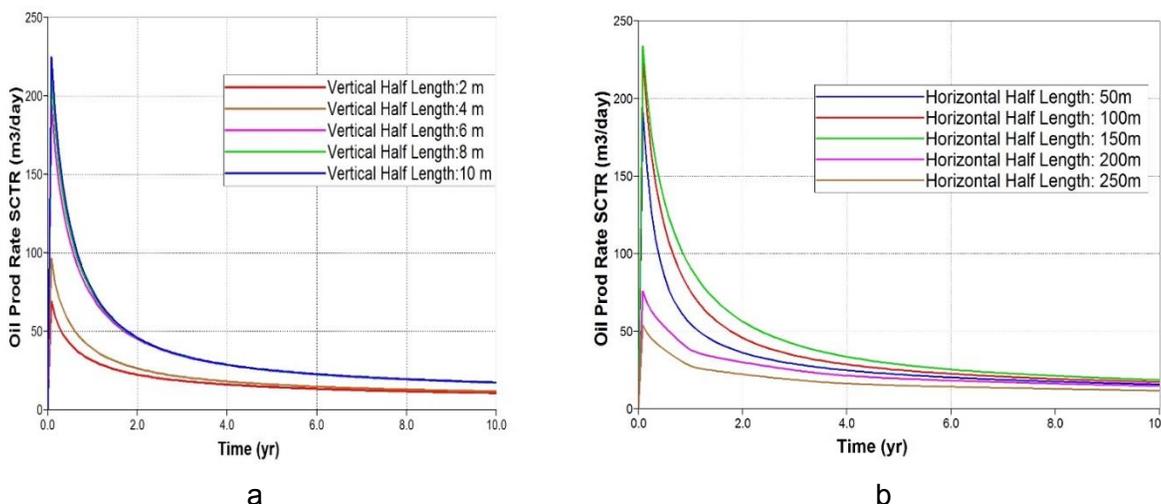
In this study, CMG IMEX is used for tight oil reservoir simulation. The modeled volume is 1,000m in length (I-direction) by 2,900m in width (J-direction) by 56m in thickness (K-direction), and 20 (I-direction) × 58 (J-direction) × 56 (K-direction) grid blocks are used. The grid block size in the I-direction and J-direction is 50m. The grid top ranges from 2,000 to 2,056. Properties of the tight oil reservoir are all obtained from field data, as shown in Table 1-1.

**Table 1-1. Properties of simulation model of reservoir**

Reservoir temperature (°C)	80
Reservoir compressibility (KPa <sup>-1</sup> )	1e <sup>-7</sup>
Permeability (md)	0.08645
Reference depth (m)	2,020
Reference pressure (MPa <sup>-1</sup> )	27
Water-oil contact (m)	3,000
Bottom hole pressure (MPa)	20

A horizontal producer is placed in layer 35, and the horizontal length of the well in the J-direction is 1,000m. Two variable parameters of fractures (the horizontal fracture half length and vertical half length) are predesigned and controlled in the simulation process. There are five predesigned horizontal fracture half lengths, 50m, 100m, 150m, 200m, and 250m, and ten predesigned vertical fracture half lengths, 2m, 4m, 6m, 8m, 10m, 12m, 14m, 16m, 18m and 20m. Thus 5×10 predesigned cases are simulated to achieve their production data.

From Fig. 1-1 (a), the oil production rate decreases as time increases. The simulation results show that 10m is the optimal vertical fracture half length when the horizontal fracture half length is fixed at 100m. In addition, Fig. 1-1 (b) shows that 150m is identified to be the optimal horizontal fracture half length when the vertical fracture half length is fixed at 10m.



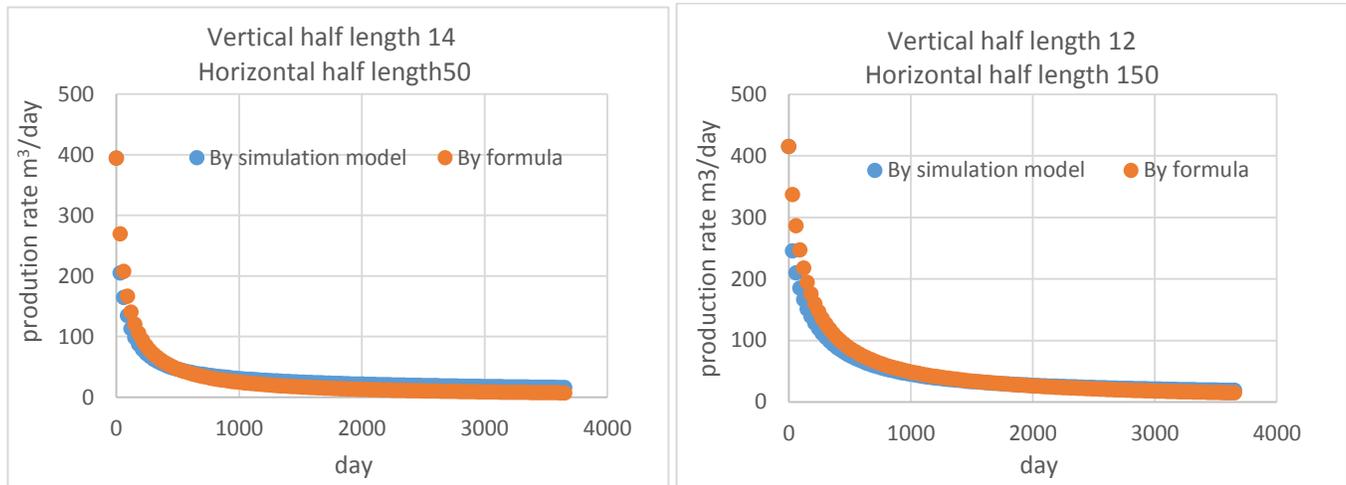
**Fig. 1-1. Production curves (a. from 5 predesigned vertical fracture half length cases with horizontal fracture half length fixed at 100m, b. from 5 predesigned horizontal fracture half length cases with vertical fracture half length fixed at 10m)**

The next step is to obtain the parameters for a decline curve based on simulated production data. There are three types of decline equations: harmonic, hyperbolic and exponential (Arps, 1954). A hyperbolic decline prediction formula is suitable for tight oil reservoirs (Mohan 2006):

$$q(t) = \frac{q_i}{(1 + bD_i t)^{1/b}}$$

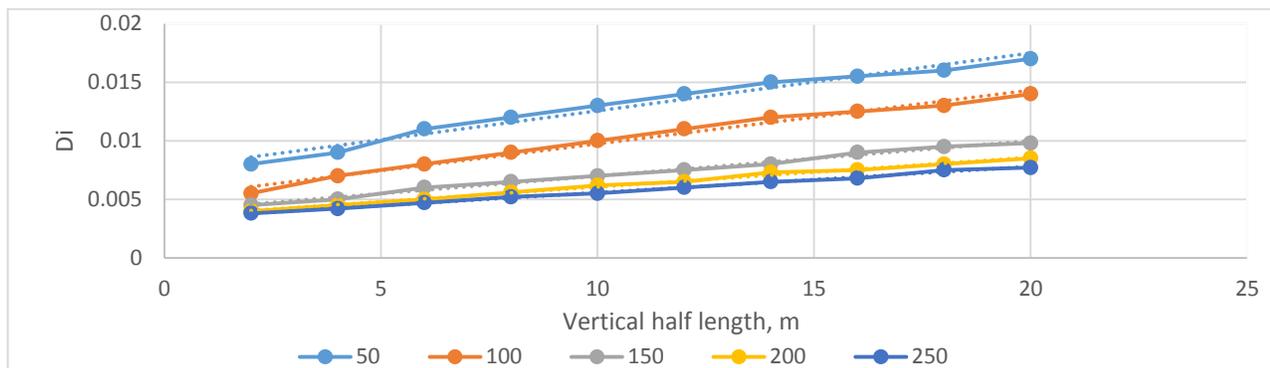
where  $q_i$  is the initial oil production rate (m<sup>3</sup>/day),  $q(t)$  is the oil production rate at time  $t$  (m<sup>3</sup>/day),  $t$  is time (day),  $D_i$  is a decline rate, and  $b$  is a parameter used in the hyperbolic formula ( $0 < b < 1$ ).

By fitting the simulation data into the Arps Decline Equation,  $D_i$  and  $b$  can be achieved for each production decline curve from the simulation results. Take the vertical fracture half length 14 and the horizontal half length 50, for example, from the 50 models.



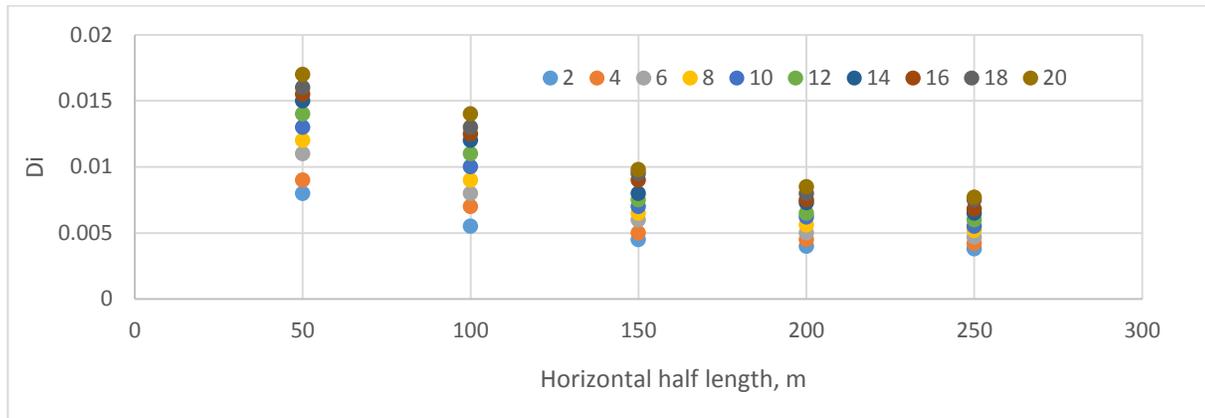
**Fig. 1-2 a & b. Fitting results of production rate curves by simulation model and formula**

Fig. 1-2 shows the fitting results for the case with the vertical and horizontal fracture half length designed as 14m and 50m, respectively. The blue curve represents the original production data from the simulation results, and the red curve is the fitting result using the Arps Decline Equation. Thus the optimal value of  $D_i$  and  $b$  can be achieved from this fitting result. In this case, the value of  $D_i$  is 0.0015 and  $b$  is 0.999. Every type of a fracture simulation model has its own suitable values of  $D_i$  and  $b$  after matching all the 50 models, and the correlation of a vertical half length with  $D_i$  and  $b$  is shown as Fig. 1-3.



**Fig. 1-3. The relation of  $D_i$  and vertical fracture half length**

These charts show that when the vertical half length increases, the value of  $b$  does not change much and  $D_i$  increases at the same time. Obviously, given the same horizontal half fracture length, the vertical half length has a linear relationship with the value of  $D_i$ .



**Fig. 1-4. The relation of  $D_i$  and horizontal fracture half length**

Fig. 1-3 represents a change in  $D_i$  with different vertical fracture half lengths when the horizontal fracture half length is fixed. All five cases show the same trend that  $D_i$  increases with the vertical fracture half length increasing. For each relationship of  $D_i$  and the vertical fracture half length, a slope can be identified. From the fitting results, the slopes decrease with the horizontal fracture half length increasing. Fig. 1-4 shows a relationship of  $D_i$  and the vertical fracture half length. For each fixed horizontal fracture half length,  $D_i$  decreases with the vertical fracture half length until it reaches the minimum value at 200m.

## Conclusions

In this paper, a relationship between parameters from a rate decline prediction formula and fracture geometry is obtained, analyzed and supported by the simulation results. For this Jilin Oilfield case, when the horizontal half fracture length increases, the value of  $b$  remains as a constant, and the value of  $D_i$  slightly decreases, but  $D_i$  increases as the vertical half length increases.  $D_i$  also owns a linear relationship with the vertical half length. The analysis shows that improving the rate decline prediction formula is able to forecast future production for tight oil reservoirs in Jilin Oilfield.

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