

PAPER • OPEN ACCESS

## Evaluation of Asymmetric Fractures on Acid Fracturing Well

To cite this article: Ke Li *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **300** 022085

View the [article online](#) for updates and enhancements.

# Evaluation of Asymmetric Fractures on Acid Fracturing Well

Ke Li <sup>1,2</sup>, Jun Zhou <sup>3,\*</sup>, Jing Yang <sup>4</sup>, Linbo Zhou <sup>3</sup>

<sup>1</sup> China National offshore Oil Corporation Research Institute, Beijing, China

<sup>2</sup> State Key Laboratory of Offshore Oil Exploitation, Beijing, China

<sup>3</sup> Sinopec Research Institute of Petroleum Engineering, Beijing, China

<sup>4</sup> School of Energy Sources, Chengdu University of Technology, Chengdu, China

\*Corresponding author e-mail: zhou\_sripe2015@126.com

**Abstract.** Because of the heterogeneity of acid corrosion, acid fracturing effect is difficult to assess, and how to make use of acid fracturing construction data to guide fracturing design have always been concerned by scientific researchers. Several shutdown processes have been existed in acid fracturing construction, this is similar to the process of injection and falloff well test. In this paper, basic principle of seepage mechanics and injection pressure drop well test interpretation theory are used to establish injection pressure drop mathematical model with considering the influences of asymmetric fractures. The influence of asymmetric fracture geometry and fracture number on pressure double logarithmic curve have been analyzed. The method presented in this paper to analyze the pressure drop data can better explain the fracture parameters and general effect of acid fracturing construction.

## 1. Introduction

Acid fracturing construction is a way to increase oil production. Through injecting acid into formation, acid-rock reaction process happens near the wellbore area to relieve pollution, connect reservoir and change the way of seepage [1]. Nolte as the representative of fracturing researchers, has been focused on how to use wellhead construction data to evaluate the effect of reservoir stimulation [2-6]. The process of acid fracturing construction is similar to that of injection pressure drop well test analysis. That is to inject a certain amount of liquids into the formation, and then record the pressure drop process. According to the variation of pressure and flow capacity with time, to analyze the formation physical property (such as permeability, skin factor, formation pressure and so on) and the parameters of fractures [7-10]. Especially when forming fractures with complex shape or fracture networks during acid fracturing construction, the existed assessment methods are not a good way to analyze fracture morphology and fracture parameters. In this paper, asymmetric fractures seepage model was established by using the injection and falloff well test interpretation theory. Combining with the pressure data of fracturing construction, the identification of fractures and the effect of construction evaluation in real time were realized, which greatly improve the success ratio of acid fracturing construction and present a great practical guiding significance.

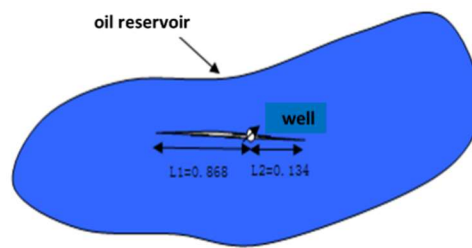
## 2. The theory of injection and falloff well test interpretation

Because of the heterogeneity of reservoir and the random distribution of rock forming mineral, there always develop asymmetric etching fractures or multiple fractures extending in different directions



Content from this work may be used under the terms of the [Creative Commons Attribution 3.0 licence](https://creativecommons.org/licenses/by/3.0/). Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.

during acid fracturing process. On this basis, this paper established injection and falloff physical model (as shown in Fig. 1), the basic assumptions are as follows: ①Horizontal infinite homogeneous reservoir, isotropy, formation thickness is  $h$ , porosity is  $\phi$ , permeability is  $k$ , initial reservoir pressure is  $P_i$ ; ② Fluid in formation is sub-compressible, viscosity is  $\mu$ , compressibility is  $C$ , the fluid flow is in accordance with the law of Darcy flow, the influence of a variety of factors such as gravity is ignored; ③Fractures are linearly distributed along the wellbore, and there are asymmetric at both ends. Fracture porosity is  $\phi_f$ , fracture height is equal to reservoir thickness and both are  $h$ , the total length of fractures is  $2X_f$ , fracture width is  $b_f$ , fracture permeability is  $k_f$ .



**Figure 1.** Seepage physical model of asymmetric fractures

Because of the heterogeneity of reservoir and the random distribution of rock forming mineral, there always develop asymmetric etching fractures or multiple fractures extending in different directions during acid fracturing process. On this basis, this paper established injection and falloff physical model (as shown in Fig. 1), the basic assumptions are as follows: ①Horizontal infinite homogeneous reservoir, isotropy, formation thickness is  $h$ , porosity is  $\phi$ , permeability is  $k$ , initial reservoir pressure is  $P_i$ ; ② Fluid in formation is sub-compressible, viscosity is  $\mu$ , compressibility is  $C$ , the fluid flow is in accordance with the law of Darcy flow, the influence of a variety of factors such as gravity is ignored; ③Fractures are linearly distributed along the wellbore, and there are asymmetric at both ends. Fracture porosity is  $\phi_f$ , fracture height is equal to reservoir thickness and both are  $h$ , the total length of fractures is  $2X_f$ , fracture width is  $b_f$ , fracture permeability is  $k_f$ .

According to the basic idea of point source function and the fundamental principle of poromechanics, we can deduce the basic solution of instantaneous point source of infinite formation with closed boundary at top and bottom is:

$$\bar{\gamma} = \frac{1}{4\pi} \sum_{-\infty}^{+\infty} \left\{ \frac{\exp(-\sqrt{u} \sqrt{R_D^2 + (Z_D + Z_D' - 2nZ_{eD})^2})}{\sqrt{R_D^2 + (Z_D + Z_D' - 2nZ_{eD})^2}} + \frac{\exp(-\sqrt{u} \sqrt{R_D^2 + (Z_D - Z_D' - 2nZ_{eD})^2})}{\sqrt{R_D^2 + (Z_D - Z_D' - 2nZ_{eD})^2}} \right\} \quad (1)$$

Where  $\gamma$  is fundamental solution of instantaneous point source in lagrangian space;  $u$  is lagrangian variables;  $n$  is integer;  $R_D^2 = (x_D - x_D')^2 + (y_D - y_D')^2$  is dimensionless distance;  $x_D = \frac{x}{l} \sqrt{\frac{K}{K_x}}$  is dimensionless X coordinates of shotpoint;  $y_D = \frac{y}{l} \sqrt{\frac{K}{K_y}}$  is dimensionless Y coordinates of shotpoint;

$z_D = \frac{z}{l} \sqrt{\frac{K}{K_z}}$  is dimensionless Z coordinates of shotpoint;  $z_{eD} = \frac{z_e}{l} \sqrt{\frac{K}{K_z}}$  is dimensionless formation thickness;  $x'_D = \frac{x'}{l} \sqrt{\frac{K}{K_x}}$  is dimensionless X coordinates of test point;  $y'_D = \frac{y'}{l} \sqrt{\frac{K}{K_y}}$  is dimensionless Y coordinates of test point;  $z'_D = \frac{z'}{l} \sqrt{\frac{K}{K_z}}$  is dimensionless Z coordinates of test point.

Lagrangian transformation to equation (1), we can get the expression of elementary solution of instantaneous source function in Laplace space is:

$$\bar{\gamma} = \frac{1}{2\pi z_{eD}} [K_0(R_D \sqrt{u}) + 2 \sum_{n=1}^{\infty} K_0(R_D \sqrt{u + \frac{n^2 \pi^2}{z_{eD}^2}}) \cos(n\pi \frac{z_D}{z_{eD}}) \cos(n\pi \frac{z'_D}{z_{eD}})] \quad (2)$$

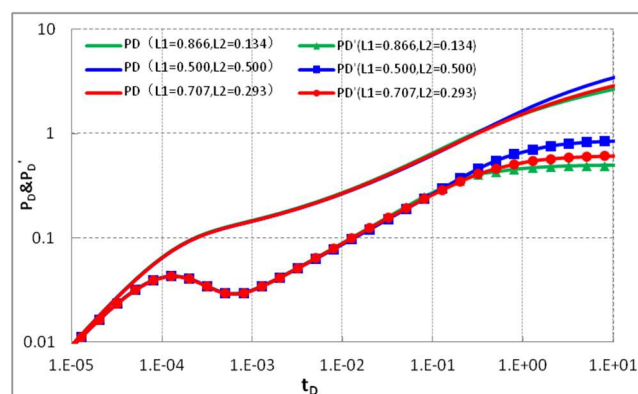
Where  $K_0()$  is zero-order Bessel function.

Assuming that the well is located at  $(x_D, 0, z_e / 2)$ , the length of the etching fracture is  $2L_f$ . By integrating the basic solution of the simplified point source along the direction of the etching fracture, we can get the response function of bottom pressure in Lagrangian space with asymmetric etching fractures is:

$$\bar{P}_D(x_D, u) = \frac{1}{2u\sqrt{u}} \left[ \int_0^{\sqrt{u}(1-x_D)} K_0(\xi) d\xi + \int_0^{\sqrt{u}(1+x_D)} K_0(\xi) d\xi \right] \quad (3)$$

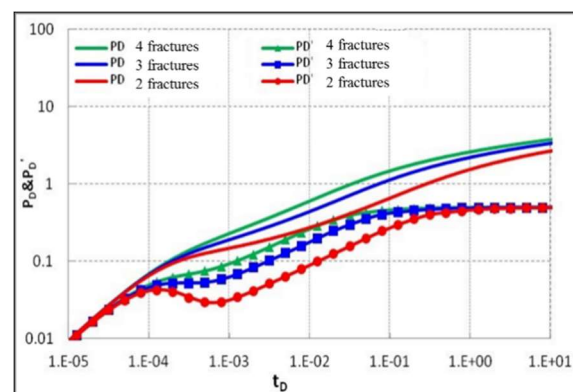
### 3. Analysis of influential factors to Injection Pressure Drop Curve

Based on the asymmetric fractures seepage mathematical model established in this paper, we gained the double logarithmic plate of the bottom pressure data by numerical simulation, thus analyzed the influence of asymmetric degree on bottom hole pressure (Fig. 2). Due to the length of fractures is different, the time of pressure swept to the distal end of fractures in two directions is different, this will affect the horizontal value of radial flow phase on log-log plot. Flow balance within reservoir, namely, after the system into radial flow stage, the slope of derivative double logarithmic curve of symmetrical fractures is zero, which is a horizontal line. However, for the case of asymmetric fractures, the horizontal value is not zero, and the severer the asymmetric degree is, the lower the derivative curve position is, correspondingly, the lower the pressure curve position is.



**Figure 2.** The influence of asymmetric degree on bottom hole pressure

During acid fracturing construction, due to the use of different acid-fracturing technique, such as volume or steering acid fracturing technique [11-12], will develop complex multiple fractures. Therefore, the influence of multiple etching fractures on bottom hole pressure was calculated (Fig. 3). Seeing from Fig. 3, the number of fractures mainly affect the duration and position of the linear flow period. When the length of fractures is constant, with the increase of fracture number, the double logarithmic curve is gradually difficult to show a linear flow stage, and the position of the pressure and derivative curve increases with it. This is due to the fact that the more the fracture number is, the higher the average equivalent permeability in transformation range is, the faster the flow velocity of oil and gas in multiple fractures is, and the difference between reservoir and fracture is difficult to exhibit. If the fracture number is small, therefore the double logarithmic curve is prone to a linear flow stage with a slope of  $1/4$ , and the position of the pressure and derivative curves is lower.



**Figure 3.** The influence of fracture number on bottom hole pressure

#### 4. Conclusion

(1) The asymmetry and number of fractures have an obvious effect on the double logarithmic curve. Utilizing the injection and falloff well test theory to explain the acid fracturing construction data can distinguish the validity of fractures and fracture morphology, and can better to guide the design of acid fracturing construction and the site construction decision.

(2) Though the interpretation of injection and falloff well test theory, we can gain the change of fracture parameters during fracturing construction. It is important to timely adjust the program of reservoir stimulation and to improve the yield of stimulation.

#### Acknowledgments

This work was financially supported by National Natural Science Foundation of China (Grant No. 51674044).

#### References

- [1] Huang Xia, Cheng Lijun, Li Kezhi, et al. Application of deep acid fracturing technology in northeastern Sichuan carbonate reservoir. *Natural Gas and Oil*, 2012; 30(3):40—44.
- [2] Nolte K,G. Determination Of fracture parameters from fracturing pressure decline. *Applied Mechanics & Materials*, 1979; 152 (8):585—588.
- [3] Nolte K,G. Determination of proppant and fluid schedules from fracturing-pressure decline. *SPE Production Engineering*, 1986; 1(4):255—265.
- [4] Barree R,D, Mukherjee H. Determination of pressure dependent leakoff and its effect on fracture geometry. *SPE Annual Technical Conference and Exhibition*. Denver :Society of Petroleum Engineers, 1996:85—94.
- [5] Zou Dongli. Evaluation of horizontal well acid fracturing effect in carbonate reservoir of T oilfield. Chengdu: Southwest Petroleum University,2014.

- [6] ChenXiang. Evaluation of acid fracturing effect in fracture-vug type carbonate reservoir of M oilfield. Chengdu: Southwest Petroleum University,2016.
- [7] Cui Liping, He Shunli, Wang Jincheng, et al. Well testing evaluation of vertical fracture in low permeability reservoir. Science Technology and Engineering, 2009;9(18):5465—5468.
- [8] Liu Yaoge, Wang Lei, Yin Rongwang, et al. Well test interpretation method by injection/fall off test data for low permeability well. Well Testing, 2014; 23(3):1—4.
- [9] Chen Lixin, Cheng Hanli, Zhu Yi, et al. Transient well testing evaluation of fractured vuggy carbonate reservoir after acid fracturing. Well Testing, 2016;43(2):33—36.
- [10] Zhao Wen, Zhang Suian, Sun Zhiyu, et al. Evaluative research for the fracture complexity after fracturing based on the G-function curves analysis. Science Technology and Engineering, 2016;16(33):29—33.
- [11] Xu Binwei , Li Kezhi, Qin Yuying, et al. Study and application of acid fracturing technology with diversion acid in Daniudi gas field. Fault-Block Oil & Gas Field,2013;20(2):232—235.
- [12] Li Nianyin, Dai Jinxing, Zhang Qian, et al. A new technology for the effective development of tight-gas carbonate reservoir——volume acid fracturing. Science Technology and Engineering, 2015;15(34):27—38.