

Research Status of Perforation Parameter Optimization of Different Well Types at Home and Abroad

Ke Xu

School of Xi'an shiyou University, Xi'an 710065, China

Abstract

Perforation is a process that penetrates the casing and cement sheath to establish a production channel for oil and gas. Reasonable perforation parameter design is the key to removing contamination and releasing production capacity. Perforation technology can improve the connection between the oil and gas layer and the formation to the greatest extent, thereby significantly increasing the production efficiency of crude oil. Nowadays, perforation technology is widely used in oil and gas field development. Therefore, optimizing perforation parameters is of great significance for improving the production efficiency of oil reservoirs. This paper investigates the current research status of perforation parameter optimization by scholars, and sorts out the research on three types of wells: vertical wells, horizontal wells, and deviated wells respectively.

Keywords

Perforation Parameters; Vertical Well; Horizontal Well; Deviated Well.

1. Introduction

In the process of oil and gas field development, perforation completion technology is like a "golden key" to unlock underground treasure, and its importance is self-evident. This technology creates a critical connection between the formation and the wellbore by creating a channel through the casing and cement ring, providing the necessary conditions for oil and gas extraction. With the advancement of oil and gas exploration and development to deep, ultra-deep and unconventional fields, the importance of perforation completion technology has become increasingly prominent, which is directly related to the production capacity of oil and gas Wells and the development efficiency of the whole oilfield.

By optimizing the perforating parameters and technology, the seepage condition near the well can be effectively improved and the production of a single well can be increased. In the development of low permeability oil and gas reservoirs, this role is particularly obvious. In the development of complex oil and gas reservoirs, perforation completion technology shows unique advantages. For special reservoirs such as high temperature and high pressure, ultra-deep and ultra-low permeability, customized perforating schemes can overcome development difficulties and realize economic and effective development. In the development of carbonate reservoir, the organic combination of acidizing fracturing and perforation has greatly improved the development effect.

Perforation completion technology plays an important role in reducing development cost. The development cost per unit of production can be reduced effectively by increasing the production rate of single well and extending the stable production period. In the development of marginal oil and gas fields, this economic value is more significant.

At present, many scholars have conducted in-depth research on perforation completion technology. This paper investigates the current research status of scholars on perforation parameter optimization, and sorts out the research on three kinds of well types: vertical well, horizontal well and deviated well.

2. Research Status of Vertical Well Perforation Parameter Optimization at Home and Abroad

As early as 1942, M. Uskat first presented an analytical method to deal with the problem of the effect of perforation parameters on oil well productivity, but it was used to represent the perforation hole with a mathematical confluence of spiral distribution around the hole, and the hole did not extend into the formation[1]. In the early 1950s, R.A.Howard, M.S.T. Watson, J.M.Modowell and M.Uskat conducted electrical simulation studies on the relationship between perforation parameters and well productivity. Due to the limitations of various conditions assumed at that time, these early electrical simulation results had large errors and poor practicability[2]. In 1966, M.H.Harris studied for the first time the influence of perforating parameters such as hole depth, hole density, aperture and phase Angle on oil well productivity under ideal perforating conditions by using finite difference mathematical model[3]. The calculated results were given by a series of curves in the form of skin coefficient, which has great practicability. In fact, during the perforating process, due to the strong impact and accumulation of the perforating charge on the rock, a low permeability zone will be formed around the hole, that is, the perforating compaction damage zone. Bell et al. conducted experimental studies on small-diameter core targets, and the results showed that the permeability of the perforated compaction damage zone was about 10%-20% of the original core permeability, and the thickness of the compaction zone was about 13mm. This compaction damage zone had a very important impact on the productivity ratio. Therefore, the above study did not consider the impact of perforation compaction damage zone on productivity, and its perforation model was not accurate enough. In 1974, J.A. lotz et al. used the finite element method for the first time to evaluate the productivity of perforated Wells with compaction zones, and the holes were close to the actual circular holes. However, he limited the study to two-dimensional flow and could not consider the effects of phase, hole density and perforation format. In 1981, S.OCK first used a three-dimensional finite element mathematical model to study the effects of various perforation parameters such as compaction zones and contamination zones on well productivity, but the holes were treated as wedges, so the simulation accuracy was poor. In 1985, S.M. ariq and M.J.Chara et al. extended the finite element method to the study of perforation productivity in heterogeneous, shale interbeds and natural fractures, and found that the formation heterogeneity strongly affects the perforation completion efficiency. In 1988, S.M. ariq and M.J.Chara proposed a general analytical model to evaluate the skin coefficient of perforation completion, which was obtained by accurate finite element simulation to quantify the influence of borehole and vertical flow. The study included the effects of perforation damage and formation anisotropy, resulting in a better understanding of the relative effects of various perforation parameters on well productivity[4,5].

On the basis of finite element numerical simulation, Lang Zhaoxin, Zhang Lihua et al., from China University of Petroleum, used nonlinear regression method to describe the interaction between perforation parameters, and obtained 21 regression formulas under seven perforation formats and phases in three different cases[6]. The concept of limiting yield ratio was introduced for the first time, and some exact solutions were obtained. In addition, Tang Yula, Pan Yingde et al. from Southwest Petroleum University studied core target test, perforation flow efficiency and damage evaluation of perforation compaction zone by using finite element method, focusing on the three-dimensional flow rule of perforating well bottom and the influence of various parameters on perforation completion productivity[7].

3. Research Status of Horizontal Well Perforation Parameter Optimization At Home and Abroad

By establishing a semi-analytical model and dimensionless the model, foreign scholars comprehensively discussed the influence of each perforating parameter on the inflow performance of horizontal Wells through iterative solution. M.J. andman and W.H. oldthorpe studied the optimization of perforation design, trying to control the production of horizontal Wells by optimizing the perforation distribution.

Xiong Youming et al. from Southwest Petroleum University in China introduced horizontal well drilling damage skin coefficient and perforation damage skin coefficient based on the ideal open hole horizontal well productivity (Joshi formula) and modeled the form of vertical well perforation completion[8]. In this paper, the mathematical model of productivity prediction and the analytical formula of skin coefficient are given for four perforating series of horizontal well completions, including casing perforation completion, wire-wrapped screen completion in perforating casing, gravel pack completion in perforating casing and pre-packed gravel screen completion in perforating casing. At present, the numerical simulation of perforation completion is only limited to finite difference. Liu Yajun et al., China University of Petroleum, used the finite difference method to numerically simulate the factors that affect the production after perforation completion of horizontal Wells, including hole depth, hole density, hole diameter and hole phase, and conducted sensitivity analysis for different hole depth, hole density and hole diameter. Zhou Shengtian et al. from China University of Petroleum studied the influence of perforating parameters on horizontal well seepage[9].

4. Research Status of Deviated Well Perforation Parameter Optimization At Home and Abroad

The development of deviated well perforation completion technology can be traced back to the 1980s. With the development of directional drilling technology, inclined well has gradually become an important means to develop complex oil and gas reservoirs. In the early stage of inclined well perforation completion, the vertical well technique was mainly used, but the perforation effect was not ideal and the completion quality was difficult to be guaranteed due to the existence of inclined Angle. Since the 1990s, perforation completion technology for deviated well characteristics has been developed. Researchers gradually realized the influence of well inclination Angle on perforation trajectory, casing strength and completion fluid performance, and carried out specific studies. At this stage, key technologies such as directional perforating technology, high-strength casing and new completion fluid emerged successively, which laid the foundation for the development of deviated perforating completion technology. In the 21st century, with the progress of computer technology and material science, inclined well perforation and completion technology has ushered in a period of rapid development. Numerical simulation technology is widely used in perforating parameter optimization and completion design, new composite materials are applied in casing and completion tools, and intelligent perforating systems begin to appear. These technological advances have greatly improved the efficiency and quality of deviated well perforation completion, and promoted the wide application of this technology in the development of complex oil and gas reservoirs.

The research shows that with the increase of well inclination, the perforation trajectory is easily deflected, resulting in irregular perforation and affecting the oil and gas inflow efficiency. To this end, the researchers proposed a numerical simulation based perforation parameter optimization method, by considering the well inclination Angle, formation stress, casing strength and other factors, to determine the optimal perforation density, phase Angle and perforation charge type. In addition, the application of directional perforating technology has

also effectively improved the perforating effect of inclined Wells and increased the productivity of oil and gas Wells.

After decades of development, inclined well perforation completion technology has become an important means to develop complex oil and gas reservoirs. Through the continuous progress of key technologies such as perforation parameter optimization, completion fluid performance improvement and wellbore stability control, deviated perforation completion technology has played an important role in improving oil and gas recovery and reducing development costs. However, the technology still faces many challenges in the face of increasingly complex reservoir conditions. In the future, emphasis should be placed on the development of intelligent perforation technology, new completion materials and accurate numerical simulation methods, and the integration application with other stimulation technologies should be strengthened to further improve the effect and adaptability of deviated well perforation completion technology, and provide strong support for the efficient development of oil and gas fields.

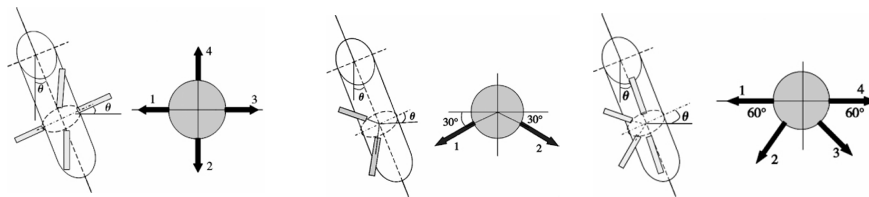


Fig 1. Layout diagram of deviated well

5. Summary

According to literature research, domestic and foreign scholars have conducted a lot of research on the optimization of perforation parameters in oil and gas Wells, but there are few studies on the optimization of perforation parameters in inclined Wells, and few scholars study the optimization of perforation parameters under different reservoir conditions. At present, the research methods can be divided into three categories: analytical model, numerical model and laboratory simulation. Each of the three methods has its own advantages and disadvantages. The analytical model (such as M. uskat model) is faster, but it ignores too many influencing factors. The error of calculation results is large. Based on the hydropower similarity theory, the laboratory simulation can only simulate the perforation pressure drop under steady seepage, and the cost becomes higher and higher with the increase of the number of scheme groups. The numerical model can consider the actual perforation situation well, and the calculation accuracy is high, which is one of the important development directions in the future.

References

- [1] Muskat, Morris. "The Effect of Casing Perforations on Well Productivity." *Trans.* 151 (1943): 175–187.
- [2] McDowell, James M., and Morris Muskat. "The Effect on Well Productivity of Formation Penetration Beyond Perforated Casing." *J Pet Technol* 2 (1950): 309–312.
- [3] Muskat, Morris. "The Effect of Casing Perforations on Well Productivity." *Trans.* 151 (1943): 175–187.
- [4] Tariq, S. M., Ichara, M. J., and L. Ayestaran. "Performance of Perforated Completions in the Presence of Anisotropy, Laminations, or Natural Fractures." *SPE Prod Eng* 4 (1989): 376–384.
- [5] Karakas, Metin, and S. M. Tarlq. "Semianalytical Productivity Models for Perforated Completions." *SPE Prod Eng* 6 (1991): 73–82.
- [6] Lang, Z.X, Zhang, L.H, Zhu, J.C, et al. Development of perforating engineering application software WPSYS-A [J]. *Journal of Petroleum University (Natural Science Edition)*,1992,(06):42-48.

- [7] Pan, Y.D, Tang, Y.L, Feng, Y.P, Productivity prediction and optimization design of perforating completion parameters [J]. Acta Petrolei Sinica,1991,(02):61-71.
- [8] Xiong, Y.M, Huang, C, Liu, X.W, et al. Research on optimization design of perforation completion parameters in gas field [J]. Fault Block Oil & Gas Field,2012,19(06):813-816.
- [9] Zhou, S.T, Hole density optimization analysis of perforated horizontal Wells [J]. Petroleum Drilling Techniques, 2007,(05):55-57.
- [10] Wang, M.J, Lian,Z.H, Xing,J.B, et al. Optimization of productivity ratio of perforation completion in inclined and vertical Wells [J]. Drilling & Production Technology,2012,35(04):22-24+122-123.