Research and application on wellbore integrity technology for Integration of Oil Recovery, Well Completion and Drilling

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Abstract. Huabei oilfield has entered the middle and late periods of the development, and a series of problems such as casing damage, casing deformation, restricted measures and eccentric wear of staff and tube are gradually exposed in the development process[1,2], which affect the development benefit of oilfield, and the wellbore integrity is closely related to the development benefit. Therefore, in order to ensure the qualified wellbore conditions, huabei oilfield put forward the design concept of “Integration of Oil Recovery, Well Completion and Drilling”, the engineering design system of multi-professional coordinated and unified “Integration of Oil Recovery, Well Completion and Drilling” are constructed, the optimization design of drilling trajectory, casing and frac fluid system was carried out. The application shows that the design prolonged the life cycle of oilwell effectively, which of great significance for single well productivity improvement and benefit development.

1.Introduction

The development benefit of an oil field(oil well)is proportional to the cumulative production in the life cycle, cumulative production is mainly related to two aspects:the first one is development policy, the second one is the development life of oil well which is directly related to the integrity of wellbore. As a highly comprehensive technical management work, the integrity of wellbore involves geology, drilling, completion, oil production, reservoir reconstruction and other multi-disciplines, multi-professional[3,4].

In the process of oilfield development, the traditional way of technological design practice is to use the relay scheme establishment(Figure 1). due to the different focus of all departments in the process of programming, the demand of oil recovery is not taken into account adequately in the previous scheme design. This result in unreasonable wellbore structure, reduced wellbore life, increased difficulty of oil recovery and other problems in the process of development[5-8], which seriously affected hourly productivity and benefit of oil well. Therefore, how to consider the later oil recovery demand at the beginning of the drilling process design, ensure the qualified wellbore conditions, and maximize the benefit of the whole life cycle of the oil well has become an urgent problem to be solved.
2. The design concept of Integration of Oil Recovery, Well Completion and Drilling

In view of the above problems, Huabei Oilfield has put forward the design concept of "Integration of Oil Recovery, Well Completion and Drilling" \(^{(9)}\), that is, adopting the research ideas of "reverse analysis, forward design and comprehensive balance". On the premise of analyzing factors affecting oil production efficiency, such as pump inclination, casing quality and fluid supply capacity, tracing the crux, changing the design concept, the drilling and completion is carried out on the premise of fully considering oil production demand. The scheme design establishes a set of design mode which comprehensively considers influencing factors such as drilling quality, subsequent fracturing and acidification, operation(Figure 2), so as to improve the adaptability of oil wells to later measures and ensure that qualified wellbore conditions being put into production, so that the comprehensive cost can be controlled and the life cycle of oil wells can be prolonged.

3. The design method and application of “Integration of Oil Recovery, Well Completion and Drilling”

3.1. The establishment of an evaluation system for “Integration of Oil Recovery, Well Completion and Drilling”

Based on the research idea of "reverse induction" and aimed at saving energy and reducing
consumption, the main factors affecting the benefits of oil wells in their life cycle are deeply analysed. Firstly, the factors affecting the benefits of oil wells development are analyzed and evaluated from the ground, wellbore and underground. The emphasis is to establish the correlation among the factors affecting wellbore integrity (Figure 3). For the purpose of increasing production, measures transformation and production optimization, this paper puts forward a design system of integrated wellbore integrity of “Integration of Oil Recovery, Well Completion and Drilling” basing on reservoir geology, and having coordinated and unified drilling, completion (cementing), measures and production technology.

3.2. The establishment of a design process for “Integration of Oil Recovery, Well Completion and Drilling”

According to the evaluation system, breaking through the requirements of single factor’s well trajectory, adding constraints such as reservoir evaluation, completion optimization, cementing quality, increasing production demand of measures and oil production demand and so on, a design process for “Integration of Oil Recovery, Well Completion and Drilling” is established(Figure 4), which realise the individualization, pertinence and accuracy of the design.

Figure 3. Factor correlation tree
3.3. The completeness of a design technique for “Integration of Oil Recovery, Well Completion and Drilling”

3.3.1. The enhancement of professional combination and the development of trajectory optimization design

Based on the mode of “Integration of Oil Recovery, Well Completion and Drilling”, parameters such as inclination angle of pump are added into the drilling design at the beginning of it, three-dimensional mechanics of rod&tube and simulation calculation of eccentric wear state are added into the program design process. Adhering to the principle of "one well, one simulation, eccentric wear evaluation and trajectory optimization", the foundation for prolonging the life of oil wells is laid from the source.

3.3.2. The change of design idea and the increase of casing safety life

Casing design not only considers the requirements of geology, drilling and completion, but also takes into account the safety requirements of maximum fracturing operation pressure and post-operation strength. The internal pressure strength of reservoir casing should meet the requirements of fracturing. In addition, according to the needs, establishing cementing casing optimization matching technology, using mechanical simulation software of finite element to simulate stress analysis, the occurrence of casing damage and casing change is reduced.

In view of the condition of casing damage and casing deformation caused by mudstone expansion after absorbing water, high pressure water injection, high injection-production ratio and salt-gypsum layer creep, the following aspects are optimized: the first one is to optimize cement slurry system, the second one is to optimize cementing construction technology, the third one is to optimize design of casing string in complex section.

3.3.3. The establishment of block pressure template and the optimization of drilling fluid system formulation

Firstly, according to the existing geological and pressure data, the pressure chart of the block is established, and the pore pressure of the target block is predicted by the pressure chart. Then, on the
basis of formation pressure prediction, the mechanism of wellbore instability is analyzed, and the safe density window of drilling fluid is determined, at the same time, systematic and large-scale performance evaluation of drilling fluid is carried out by laboratory experiments, influencing factors are analyzed, and the performances of drilling fluid density, water loss and reservoir protection are optimized, so as to reduce the complexity and protect reservoirs.

3.3.4. The reservoir service and continuous optimization of fracturing technology
Dynamic and static data of the block are analyzed in detail, combining with single well reservoir development and transformation needs, fracture simulation is conducted, and fracturing technology and fracturing materials are optimized to achieve the optimal transformation program (Figure 5).

On the basis of the evaluation of reservoir modification effect in the early stage, according to the geological characteristics of the oilfield, combing the mature fracturing fluid systems used at present, analyzing their respective advantages and adaptability, the fracturing fluid system adapted to the block and the fracturing fluid formulation are optimized, which reduced the dosage of thickening agent, the residual rate, the damage to the reservoir, and increased the production of single well.

3.4 Application situation
From 2016 to 2018, according to the design requirements of “Integration of Oil Recovery, Well Completion and Drilling”, well trajectory design for 465 directional wells have been optimized and calculated in Huabei Oilfield. By calculating the force analysis of rod and tube, the number of centralizers of each well trajectory under the same oil production conditions, combining with drilling footage and other factors, the optimum well trajectory is synthetically optimized, and the optimum rate of well trajectory is 100%. Through comparative analysis of data before and after the implementation of “Integration of Oil Recovery, Well Completion and Drilling”, it can be seen that after the implementation of it, three data such as angular change rate, low-efficiency well proportion and wellbore load continued to decline, the implementation of pump inspection cycle extended by 10.14%, the system efficiency increased by 2.82 percentage points, and the daily power consumption decreased by 16.86% compared with the previous year.

4. Conclusion
1. The design of “Integration of Oil Recovery, Well Completion and Drilling” breaks the traditional relay design mode, through changing the design concept, and fully taking into account the demand of later oil production, a design mode which comprehensively considers the drilling quality and the influence factors of subsequent fracturing, acidification and operation is established, which improves the adaptability of oil wells to later measures and prolongs the life cycle of oil wells.

2. According to the research idea of "reverse induction", with the ultimate goal of energy saving
and consumption reduction, this paper deeply analyses the main factors affecting the benefits of oil wells in their life cycle, establishes the correlation among the factors. A evaluation system with coordinated and unified multi-subject and multi-profession based on reservoir geology is constructed, which is, so as to realize the organic combination of drilling trajectory design and later oil production.

3. The design of “Integration of Oil Recovery, Well Completion and Drilling” utilizes multi-professional cooperation, innovates and optimizes wellbore integrity design technology. It innovates and develops drilling process optimization design, improves casing quality optimization design, increases casing safety life, after application, pump inspection cycle is greatly increased; the design of “Integration of Oil Recovery, Well Completion and Drilling” innovates and optimizes drilling fluid system formulation and fracturing fluid formulation, reduces reservoir damage, improves single well production. And ultimately, single well production is improved, the individualized design is realized and the pertinence and accuracy of the scheme are improved.

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