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ScienceDirect

Natural Gas Industry B 5 (2018) 212–218

www.elsevier.com/locate/ngib

Research Article

Anti-channeling cementing technology for long horizontal sections of shale gas wells☆,☆☆

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Received 20 July 2017; accepted 25 October 2017
Available online 8 June 2018

Abstract

Large-scale hydraulic fracturing combined with horizontal well drilling is the key technology in shale gas development. But poor cementing quality is a crucial bottleneck restricting well completion and reservoir stimulation. In this paper, the shale gas development blocks in the Sichuan Basin were taken as the examples to explore the process and support measures that can be used to keep the mechanical integrity of cement sheath under the effect of hydraulic fracturing. It is indicated that the near-bit three-centralizer drifting BHA used for casing stiffness simulation can decrease the casing running difficulty in the long horizontal section of a shale gas well and increase the time efficiency and safety of casing running; that the flushing efficiency of high-efficiency oil flushing spacer fluid system is higher than 90% from room temperature to 120 °C, so it can guarantee the displacement efficiency of cement slurry to the oil-based drilling fluid and the effective cementing of borehole wall; that the performance of anti-channeling ductile cement slurry used in the cementing of long horizontal sections in this area after it is set is confirmed, with the elastic modulus of set cement being lower than 7 GPa and triaxial strength being higher than 40 MPa, so as to alleviate or avoid the damage to cement sheath in the process of fracturing; and that cementing quality is improved by applying the support technologies, e.g. drilling fluid adjustment, pre-stress cementing and ground high-pressure pumping. During 2015–2016, these cementing technologies were applied in 85 wells in the Sichuan Basin. The average well depth of these wells is 4832 m, the average length of horizontal sections is 1560 m and the quality rate of well cementing is 89.58%. During the waiting-on-cement (WOC) time after well cementing, there is no sustained casing pressure. And gas channeling in the annulus during well drilling, completion and test is improved remarkably. It is concluded that this suite of technologies can guarantee and improve the cementing quality of long horizontal sections in shale gas wells and provides good cementing conditions for shale gas development.

Keywords: Shale gas; Horizontal well; Cementing; Casing running; Anti-channeling ductile slurry; Spacer fluid; Set cement; Strength; Elastic modulus; Sichuan basin

With the advancement of shale gas horizontal well drilling technology, the length of horizontal section is also increasing – from 500 to 1000 m in the stage of initial shale gas development to more than 1500 m now. Some well completion technologies have become incompatible [1]. For example, casing running is a difficult job in such a long horizontal section. In some wells, the time of casing running even exceeds 10 days. The stages of fracturing operation have increased from a few to 20–30 now. The popularization of

☆ Project supported by the National Major Science and Technology Project "Development of large-scale oil/gas fields and CBM" – "New technologies for improving the cementing quality and wellbore integrity under the condition of large-scale volume fracturing" (No. 2016ZX05022-005).
☆☆ This is the English version of the originally published article in Natural Gas Industry (in Chinese), which can be found at https://doi.org/10.3787/j.issn.1000-0976.2017.10.008.
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Peer review under responsibility of Sichuan Petroleum Administration.

https://doi.org/10.1016/j.ngib.2018.04.008

large-scale volume fracturing technology calls for higher requirements of cementing performance, cementing quality and wellbore integrity.

1. Difficulties

1.1. It is very difficult to safely and smoothly run casing in a horizontal well

Due to the long horizontal section of shale gas horizontal well, the casing in the high angle and horizontal sections may possibly attach to the wellbore. With the increase of horizontal section length, the frictional resistance increases significantly. Because of the low effective weight of the casing, it is difficult to overcome the frictional resistance through the weight of the casing itself during the casing running process.

Well trajectory is complex. The cluster well platform established under the "factory-like" production mode of shale gas has a typical three-dimensional horizontal trajectory. Generally, the mode of "vertical-building-twisting-building-horizontal" sections is used. Due to the relatively distorted wellbore trajectory and a large rate of change at a full angle, in addition to the change in formation strata encountered during drilling and the anti-collision operation of adjacent wells, the actual wellbore trajectory is more complicated than the designed trajectory (Fig. 1).

Shale gas wells must be fractured in multiple stages to meet the industrial production standards. However, the tool string required for completion is complex and is largely susceptible to damage during casing running. There are limited technical measures for the case when the casing running encounters resistance.

1.2. Application of oil-based drilling fluid has a great influence on the cementing quality

Oil-based drilling fluid has the characteristics of high viscosity and strong adhesion, so it requires higher displacing energy. Moreover, oil-based drilling fluid is less compatible with cement slurry. Once meeting cement slurry, it will become viscous, thus making it more difficultly to be displaced. As a result, there is higher pump pressure more potential risks.

When the wellbore stays in the oil-based drilling fluid environment for a long time, oil film is generated on (attached to) the surface of the wellbore and the casing wall, thus forming a "lipophilic and hydrophobic" environment. If the oil film cannot effectively be removed to change the wetting environment, annulus micro-gap will occur, eventually resulting in failure of hydraulic seal of cement sheath.

Cement slurry mixed with oil-based drilling fluid will seriously affect the compressive strength of set cement. Test results show that the compressive strength of set cement will reduce by 50% when the mixing ratio of cement slurry to oil-based drilling fluid is 9:1.

1.3. Wellbore integrity requirements are high when large-scale staged fracturing is carried out

Great cementing quality and set cement properties are important guarantees for the long lifecycle of shale gas wells and the effectiveness of hydraulic fracturing. Cement slurry used for cementing of shale gas horizontal well should: ① be stable without settlement, and no channeling in the horizontal section; ② have less leakage and no reservoir damage; ③ be capable of anti-gas channeling, and have properly controlled thickening time; ④ have reasonably controlled rheology and a high replacement efficiency; and ⑤ form set cements with a good mechanical performance, small elastic modulus and a high compressive strength. Furthermore, the design of shale gas well cementing should consider not only the zone isolation, but also the requirements of wellbore integrity in subsequent large-scale staged fracturing stimulation.

2. Cementing technology

2.1. Casing running in a horizontal well

A lot of researches have been done on the casing running in extended reach horizontal wells around the world [2,3]. However, these theoretical studies are still far from the actual situations in the field because of the complicated relationships between the frictional force of the string and such factors as mud cake lubricity, rock properties, borehole types, string structure and wellbore geometry. In order to ensure that the casing is safely and quickly run in hole, as the most effective practice on site, the bottom hole assembly (BHA) with simulated casing string stiffness is used for drifting and special well sections are pretreated to test the compatibility of strings and wellbore trajectory.

In the Weiyuan–Changning block, drifting operation was mainly completed based on simulated casing stiffness and special well section treatment. As to the special well section treatment, redressing was conducted at the kickoff point, point A and the bottom hole, regardless of blocking, except for the

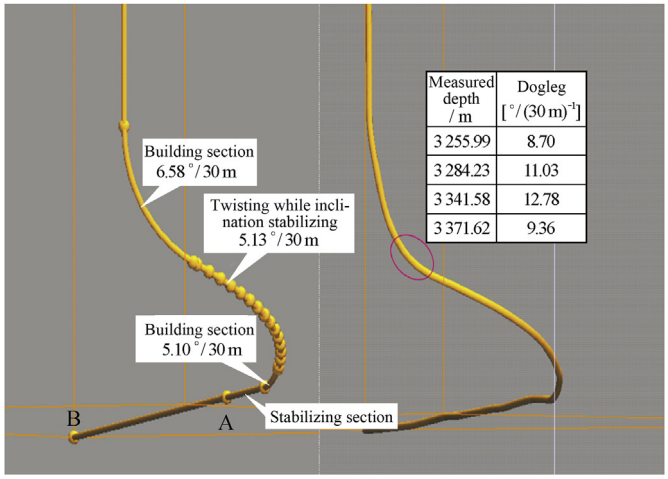

Fig. 1. Diagram of designed and actual well trajectories of Well W204H4-6.