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Challenges and Methods to Improve Well Cementing Quality for 177.8 mm Liner in Gaoshiti-Moxi Area

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Abstract

Gaoshiti-Moxi structure belt of An-Yue Sinian gas reservoir, which was China's largest monomer Marine carbonate gas reservoir up to now, located in vying-dragon female temple structure group that belong to the ancient uplift slope of the middle of Sichuan. With the exploration and development of high temperature and high pressure carbonate reservoir, a large number of challenges and problems, such as long isolation section, active oil-gas show, large temperature difference, prone to super retarding cement slurry and gas channeling at flare position, have been encountered in the cementing of 177.8 mm hang-liner. In order to solve these problems, numerous measures and methods have been put into use for reducing the safety risk of cementing and improving cementing quality. The large temperature difference channeling cement slurry system, effective anti-pollution spacer and high-pressure packer type liner hanger were developed and applied for field tests in the early stage of development. In addition, equilibrium pressure cementing technology, optimizing of centralizer placement and plasma column structure, improvement of pump displacement and hold pressure while waiting on cement were used to ensure nice displacement efficiency and cementing quality. As Moxi X well for example, the cementing quality factor of merit was 40.29% and the qualification rate was up to 78.87% after adopting the cementing measures and methods above. The cementing quality was much higher than previous level and provided technical support for Gaoshiti-Moxi area.

Keywords

GM Area, Liner Cementing, Long Isolation Section, Large Temperature Difference, Anti-Intrude Cement Slurry

1. Introduction

Gaoshiti-Moxi structure belt of An-Yue Sinian gas reservoir, which was China's largest monomer Marine carbonate gas reservoir up to now, located in vying-dragon female temple structure group that belong to the ancient uplift slope of the middle of Sichuan. The Longwangmiao formation, which was the main development zone in central Sichuan basin, had the advantages of abundant natural gas resources, large reserves, high yield of single well and long production cycle in the region. Since 2012, with the deepening of exploration work, the oil and gas situation of the Sinian Dengying Formation had been successful, and the four sections of the lamp had been found to contain gas which would have great development potential. The well depth of Gaoshiti-Moxi structure ranged from 5300 m to 5800 m, regular five-slip wellbore configuration was used to ensure safe, fast and efficient drilling. As an important part of the drilling, cementing project has a direct influence on the development process and results. In general, the quality of casing cementing is good enough to guarantee sealing requirements in this area except the 177.8 mm hanging liner. The setting depth of it was from 5000 to 5500 m, with point of suspension at 2700 ~ 3100 m and overlapping period of 400 m in the upper casing section [1]. It was designed to Jialing river, Changxing, Maokou and other relative high pressure layer formations. As a result, it is confronted with long cementing section, large temperature difference, and easy to occur extra retarded set in the liner cementing of the deep well in Gaoshiti-Moxi area. There are many high pressure gas reservoirs, oil and gas display is active, and the bell mouth is easy to occur gas channeling. The safety density window is narrow and the leakage of cement slurry always resulted in jumped seam [2]. It is not conducive to efficient displacement since the drilling fluid density is high and cementing slurries is not compatible with the drilling fluid. The microannulus was directly caused by casing radial shrinkage which was indirectly on account of greatly reduced drilling fluid density. Problems mentioned above, such as the temperature rise of the upper wellbore, the decline strength of the cement ring, can lead to many challenges and difficulties in the later stage [3]. Since 2012, counter pressure cementing, build the pressure while waiting on cement, high density anti channeling cement slurry system and packer type liner hanger were used as the main body agent technology of the hanging anti-gas channeling liner cementing technique. The phenomenon of bell mouth channeling gas was almost eliminated and cementing quality increase year by year. It can meet the needs of follow-up operations for cementing the integrity of the wellbore.

2. Challenges of Cementing

The cementing quality problem, including low qualification rate and serious annulus belt pressure of 177.8 mm liner cementing, is more prominent. The main specific problems are as follows [4]:

1) Oil and gas displayed active in the whole seal section and gas channeling

was easy to occur by the reason of longitudinal existence of high and low pressure interlayer and multi-pressure system. The formation pressure is between 1.4 and 2.2. The upper part of the open hole section is an abnormal high pressured saltwater layer. On the contrary, the underneath layers have the relative lower pressure. Therefore, the oil and gas were darted badly while waiting on cement [5].

2) It makes cement slurry easy to occur extra retarded set in virtue of long cementing section, high bottom temperature and large temperature difference between the upper and lower position. The cementing section of 177.8 mm liner is generally from 1800 m to 2600 m. Since the bottom hole temperature is up to about 140˚C and the bell mouth temperature is merely 70˚C - 80˚C, temperature difference of upper hole and lower one reached nearly 60˚C - 70˚C. It was the high bottom hole temperature and too large temperature difference that made the cementing of the cement slurry across the medium high temperature segment, which is prone to super-retarding of high density cement system.

3) It is difficult to insure balancing pressure and stabilizing formation on account of narrow stratigraphic safety window, which would lead to blowout-lost circulation coexistence. Most of Wells, with the drilling fluid density from 2.10 ~ 2.40 g/cm^3 when finishing drilling, were lost inordinately during drilling process in Gaoshiti-Moxi area. Predicted pressure coefficient of Maokou Formation, which met with serious leakage, was about 2.0. Although drilling fluid density was 2.20 - 2.42 g/cm^3, leakage volume reached up to 1195.4 m^3 and the complex time was 329 h. Late stimulation operations showed that fracture pressure gradient is 2.4 - 2.7 g/cm^3 and safety pressure window is only 0 - 0.3 g/cm^3. It is easy to encounter loss of return due to excessive construction capacity when cementing. At the same time, anti-injection process cannot guarantee the docking of the front and back interface and sealing quality as a result of existing several leakage zone in the whole sealing section.

4) By the reason of bad compatibility between cement slurry and mud, cementing quality was always poor. It is raising dramatically of viscosity and declining of thickening time after mixed each other that affected the displacement efficiency of cement slurry and increased the risk of cementing operation.

5) The microclearance, which was caused by large elastic deformation of 177.8 mm liner after decreasing of internal pressure when the density of mud been reduced sharply to adjust target layer drilling, resulted in the protruding of gas channeling at bell mouth. Ordinarily, the drilling fluid density of 177.8 mm liner in Gaoshiti-Moxi area was as high as 2.10 - 2.40 g/cm^3, while the pore pressure of the target layer was only 1.20 - 1.30 g/cm^3. This was the most important reason why it was necessary to choose lower density which made internal pressure to been declined at least 50 MPa. Due to the difference of mechanical performance and deformation between cement ring and casing, microclearance formed to lead to a bell mouth gas channeling [6]. According to a survey, there were six wells of 177.8 mm liner cementing in seven existing gas channeling problem, which seriously affected the subsequent drilling and completion of assignments.

3. Methods for Improving Cementing Quality

3.1. Cement Slurry of Large Temperature Difference and Toughness Channeling Prevention

Two-stage cement slurry of large temperature difference and toughness channeling prevention was designed to accomplish 177.8 mm liner cementing in Gaoshiti-Moxi area. And its density ranged from 2.20 to 2.40 g/cm^3. In order to improve effectiveness of shaft sealing, the mechanical properties of the cement and strength of the bell mouth were increased by adding SD77 toughness anti channeling agent [7]. For deep well liner cementing, cement hydration process is sensitive to temperature. With the performance of strong retarding at high temperature and without retarding at low temperature, SD210 was optimized as an efficient retarder to solve "super retarding" problem which had been faced with in the 177.8 mm liner cementing of Gaoshiti-Moxi area [8]. The cement strength at the top of liner was guaranteed by improvement of the cement content in solid phase, which was designed through the tight packing theory of the slurry [9]. Once again, performance of solidification characteristics and gas channeling prevention were the key to adjust 48 h strength and the following requirements [10]. Characteristics of low filtration, good stability and short transition time help to enhance anti-gas channeling early sex. Casing cement ring-formation sealing system integrity made it possible to cement shrinkage and high tenacity.

The cement is suitable for high pressure deep well, ultra deep well cementing one-time mudding solid multiple reservoir water flooding. The top and bottom hole temperature difference caused by high temperature can be overcome slurry in under the condition of low temperature for a long time not "super retarding" phenomenon caused by the solidification, anti-gas channeling has good performance. Then, large temperature difference of long isolation section and multi-pressure series were overcome to solve anti-gas channeling layer reality problem in Gaoshiti-Moxi area.

3.2. Matching Technology for Cementing

1) High pressure sealing liner hanger

High pressure sealing liner hanger, as shown in **Figure 1**, was applied to prevent gas channeling and guarantee the excellent sealing of the bell mouth position. After the well cementing operation, annulus pressure was enhanced in case the well is not leaking and then set packer of the liner hanger. Thus, gas channeling of bell mouth was prevented effectively.

Owing to the characteristics of high sealing pressure, easy to operate, unnecessary to weigh, reliable performance and so on, XG70SFS245 × 178 type high pressure sealing liner hanger was suitable for large pressure differential liner cementing or wells which had the risk of gas channeling. Its specific parameters are shown in **Table 1**. It had been successfully applied more than ten wells of 177.8 mm liner hanging cementing in Gaoshiti-Moxi area since 2009. And then, this was an effective solution for gas seal problem of high complex wells liner

Figure 1. Schematic diagram of XG70SFS245 × 178 type high pressure sealing liner hanger.

Table 1. Specific parameters of XG70SFS245 × 178 type high pressure sealing liner hanger.

Product Model	Outside Diameter mm	Hanging Weight Ton	Drift Diameter mm	Sit Hanging Pressure MPa	Suppress Through Pressure MPa	Seal Pressure MPa	Temperature Resistance ˚C
XG70SFS245 × 178	215	<200	153	9±1	18~21	70	200

hanging cementing and tie-back cementing.

2) Balancing pressure cementing

Because of the long isolation section and large temperature difference from top to bottom, hydration speed and gelation strength development of the cement slurry was variant at different depths, which resulted in different pressure loss in the annulus. Therefore, piecewise analysis of cement slurry is imperative. The critical value of static gel strength development and loss of hydrostatic pressure are calculated according to the different period of cement hydration status. And then, cumulative cement liquid column is used to determine whether it can be stabilized or not [11]. It is the way of holding wellhead pressure while waiting coagulation that can make up for hydrostatic column pressure which reduced due to weightlessness of cement hydration. The "three pressure stability" principle was used to carry out balanced pressure cementing. To prevent annular clearance, cement ring failure analysis technology is put into use to simulate pressure changes when proceeding the next stimulation operations and casing running by software [12]. The mechanics performance index requirements of cement ring were determined by judgment of seal failure condition [13]. Increasing initial stress and expansion capacity of the cement ring, which decreased the casing shrinkage, were achieved by pressuring in annulus.

3) Enhanced displacement efficiency

For the high drilling fluid density, small annular clearance, low casing center degree, limited construction displacement and pressure in Gaoshiti-Moxi area, technical measures such as reciprocating the casing and putting the cyclone centralizer were applied to improve displacement efficiency. Moreover, correct displacement theory and excellent fluid performance could make it further efforts. Details are as follows: 1) The proper size and distance of the centralizer are used to ensure that the casing can smoothly descend to the cementing well and improve the casing moderately and displacement efficiency. In the design, professional cementing simulation software is adopted to ensure that the casing is not less than 68%. 2) Try to increase the density difference between the cement slurry and drilling fluid by reasonable design of plasma column structure. High efficiency anti-pollution spacer was selected not only to solve the problem of interface contact pollution in the process of replacement, but also to improve the affinity between interface and cement ring [14]. It can help to carry empty filter cake and gelling mud for enhancing the displacement efficiency [15]. 3) Construction simulation of cementing by large discharge capacity was needed before cementing operation to predicate whether the well would have the risk of leakage. For the well that does not satisfy the well construction requirements, the job of plugging the leak is needed to improve formation bearing pressure, which can create conditions for the realization of the large discharge capacity displacement replace.

4. Analysis of Field Application

Moxi X was served as an appraisal well in Gaoshiti-Moxi area. The fourth spudding had been completed with depth of 5070 m by applying 215.9 mm bit and drilling fluid density of 2.30 g/cm^3. Then, 177.8 mm liner was tripped to cement different pressure system. The landing depth and bell mouth position respectively were 5068 m and 2780 m. The difficulties of cementing were focused on long isolation section relatively high bottom hole temperature, active oil and gas shows and larger hole deviation. Single positive injection together with the application of large temperature difference anti channeling cement slurry and high pressure top packer liner hanger were used to enhance cementing quality.

According to the challenges of cementing in this area, two condensates and high density cement slurry was adopted. The two condensate interface was designed at 3179.65 m and the density was 2.35 g/cm^3. Before and after the pump injection of cement Slurry, the anti-pollution spacer with the density of 2.3 g/cm^3 was injected into 15 m^3 and 10 m^3 respectively. The construction displacement capacity was 1.0 - 1.2 m^3/min, and the pumping pressure was 21.0 - 23.3 MPa. A series of operations, such as pressure relief, check back, remove the cement head, pick up top drive, close the annular blowout preventer and hold the wellhead pressure at 9 MPa, had been finished before setting hang liner with high pressure packer. After 10 columns were put out of hole, keep well clean-up for a cycle and then wait on cement for 48 h. the cementing quality factor of merit was 40.29% and the qualification rate was up to 78.87%, which rised substantially compared to the average quality of 26.1% and 53.4% in 2015, as shown in **Figure 2**. The cement cementation of the following overlapping section of the

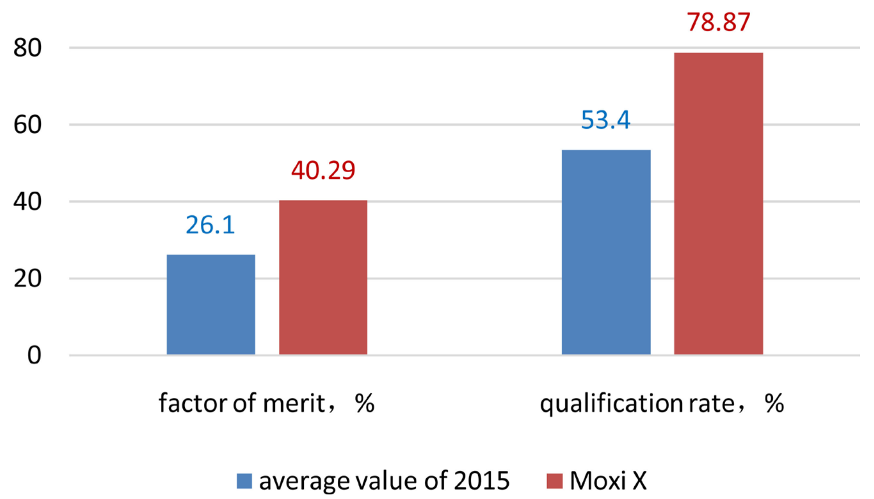

Figure 2. Increasing of cementing quality after several methods were adopted.

bell mouth was rated as high quality, and the post-secondary density drilling had not occurred in the case of the pipe, which meets the subsequent construction requirements.

5. Conclusions

1) According to analysis of difficulties in 177.8 mm hang-liner of Gaoshiti-Moxi area, the main challenges are long isolation section, active oil-gas show, large temperature difference, prone to super retarding cement slurry and gas channeling at flare position.

2) The large temperature difference toughness channeling cement slurry system, effective resistance for pollution prevention spacer, high-pressure packer type liner hanger and other technology products were formed to enhance cementing quality. In addition, the equilibrium pressure cementing technology, optimizing centralizer placement and plasma column structure, improving the construction capacity and holding pressure while waiting on cement were used to ensure good displacement efficiency and cementing quality.

3) Take Moxi X well as an example, the cementing quality merit factor was 40.29% and the qualified rate was 78.87% after technical measures and methods of cementing been applied. The cementing quality was much higher compared with previous level, which will provide technical support for improving of cementing quality in this area.

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