Study on Key Technologies of Drilling and Completion of 8000 Meter Ultra Deep Wells in Platform Basin

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Abstract. In order to solve the problems faced by 8000m class drilling and completion in tarim Basin, such as high temperature, high pressure, complicated formation, low bearing capacity of Permian tuff and development of fractures and pores in basalt segment, etc. Combined with the actual construction situation, has formed the basin area of 8000 m class drilling and well completion key technology optimization results, including optimization of casing program design and matching high crowded outside casing strength, super light corrosion resistance of titanium alloy pipe, under different working condition of the high strength developeded. These technologies, new anti-gas channeling resistance to high temperature high density cement slurry system in sectors such as advanced and practical technology. The successful application of the technology system in the 8000m class drilling in the Platform basin area has greatly boosted the exploration and development process of deep oil and gas resources, and helped improve the competitiveness of the drilling and completion market in China.

Keywords: Deep and ultra-deep well, drilling and completion technology, geological difficulties.

1. Current situation of geology and development of platform basin area

The oil and gas resource reserves in the platform basin of the Tarim Oilfield are mainly concentrated in carbonate reservoirs [1][2]. With the exploration and development of the platform basin to ultra-deep and complex areas, as well as the increase in well depth and the geology of the platform basin the characteristics have caused a series of drilling problems for 8000m-level ultra-deep wells in this area [3][4].

(1) The pressure window is narrow, and there are many sealing points. The well structure design is difficult and the risk of safe drilling is high [5][6].

The whole well traverses the Quaternary, Neogene, Paleogene, Cretaceous, Jurassic, Triassic, Carboniferous, Ordovician, Cambrian and Sinian from top to bottom, missing the Permian and mud Basin system and Silurian system [7], the special position of different formation pressures needs to be considered when designing well structure [8][9].

(2) The failure rate of directional service instruments is high, and the formation temperature exceeds the operating threshold of downhole instruments.

The average geothermal gradient in the Basin area is 1.67℃/100m, and the geothermal gradient in GL- and MS-blocks is about 2.0-2.3℃/100m, and the bottom map at 7500m depth usually exceeds 160℃, which exceeds the normal working threshold of some MWD. Instrument failures occurred in 51 of 119 directional Wells (42.8%), with a total loss time of 186.8 days.

(3) Fracture pore development, well loss risk

Permian, Ordovician and other strata leakage, among which the ordovician target layer fracture and cave development, prone to malignant leakage. Among them, the main leakage type of Permian is pore type, and it is easy to occur fracture leakage due to the influence of tectonic movement. The Ordovician is dominated by fracture-vuggy reservoirs, which are prone to large leakage. The main types of loss are slotted - cave loss and cave loss.

The above problems bring various difficulties to the drilling technology in platform basin area. Based on the design of field construction technology and equipment and the problems encountered in this paper, the key technology optimization of drilling and completion of 8000m class ultra-deep well in platform basin area is carried out.

2. Optimization and matching of ultra-deep well body structure in platform basin area

In the early stage of exploration and development of carbonate reservoirs in the platform basin, the tower standard I four-opening well structure was mainly adopted. However, with the deepening of exploration and development, it has been revealed that the deep wellbore is small in size and difficult to operate safely, which is not conducive to speed increase; the small production casing size affects the application of oil production technology and the increase in production; the drilling cycle is long and the consumables are large. Limitations of high cost of well construction.

In order to further meet the needs of the development of ultra-deep wells, increase the drilling speed, reduce the complexity of accidents, and achieve safety, speed increase, and cost reduction, for 8000m-level ultra-deep wells, combined with the lack of salt in the Middle Cambrian in the Lunnan area of the platform basin, the TB- A well structure.

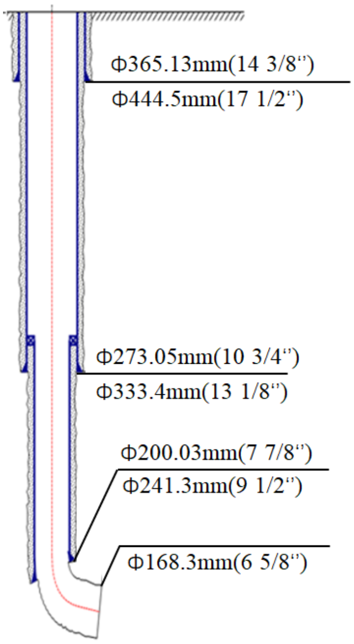

Figure 1. The structure of TB-A well

The TB-A well structure design has greatly promoted the overall drilling speed in the basin area. However, the conventional API casing has the problem of difficulty in increasing the casing level within the API series. Therefore, a supporting TB-A well structure design is designed. The non-API high-strength casing can achieve an anti-extrusion strength of more than 100MPa.

Table 1. Design and check of casing string in well H-A

Casing program	Grade of steel	Wall thickness (mm)	The ability to resist external compression			The ability to resist internal pressure		
			The intensity of the rated (MPa)	Safety factor	Stress intensity (MPa)	The intensity of the rated (MPa)	Safety factor	Stress intensity (MPa)
The surface layer	TP65	11.43	19.7	26.9	19.7	32.8	8.76	32.2
Reservoir casing	BG110S	10.92	49.9	3.52	49.8	72.5	8.21	68.7

3. High-temperature downhole tool preferred

The geothermal gradient of the GL and MS blocks in the platform basin is about 2.0-2.3°C/100m, and the bottom hole temperatures above 7500m all exceed 140°C, exceeding the normal working threshold of some MWDs. According to statistics, MWD failures occurred in the GL-3 block and MS-block in the well section exceeding 7,500m, and the drilling had to be tripped to replace the tools, and the time for some tools to enter the well was only one day. The average lost time was 3.7 days due to the depth of the well, the short after-effect of the test, and the complexity of the lost circulation.

Table 2. MWD failure statistics of GL- and MS-blocks

The serial number	Well number	Well depth	Lost time, days	Well entry time, h	Well depth, m/ temperature, °C
1	MS-A	7651	3.2	73	-
2	MS-B	7789	3.4	63.5	7727m/153°C
3	GL-A	7957	2.3	40	-
4	GL-B	7660	3.8	28.5	7850m/159°C
5		8203	4.9	129	
6	GL-C	7550	3.0	74	7607m/144°C
7	GL-D	7995	5.2	24	-

For the problem of high temperature resistance, Hybrid Thermo-P all-metal screw orientation tool is preferred. Because its stator and rotor are all metal, the theoretical temperature resistance level exceeds 400°C. In field application, the all-metal screw orientation tool can be used in the formation with the highest temperature of 250°C for more than 1000h. At the same time, the actual application shows that this type of all-metal screw does not Affected by the type of mud, it is suitable for water-based, oil-based, nitrogen, foam and other operating environments.

4. Improvement of ultra-deep drilling fluid

During the actual drilling process in the basin area, it was found that the main problem faced by the block was diabase section collapse stuck seriously. Therefore, the sulfonated anti-collapse drilling fluid system was optimized to meet the basic demand of the 7500-8000m formation at 170°C in the area. However, the drilling fluid of the system was nearly solidified after opening the tank at 200°C for 72h, and its fluidity was lost. The system is difficult to meet the temperature resistance requirement of 200°C due to the insufficient temperature resistance ability of treating agent. In the settlement stability test, the phenomenon of soft settlement and bulk formation at different temperatures is shown.

Table 3. Drilling fluid settlement stability test

Standing aging time (h)	Phenomenon description of settlement stability
190°C×72h	Liquid level height: 12.5cm, and the glass rod naturally sinks to: 6.0cm, with a little force to the end, soft heavy, lumpy.
190°C×120h	Liquid level height: 12.4cm, and the glass rod naturally sinks to: 2.0cm, with a little force to the end, soft heavy, lumpy.
190°C×168h	Liquid level height: 13.5cm, and the glass rod naturally sinks to: 2.0cm, with a little force to the end, soft heavy, lumpy.
200°C×72h	Liquid level height: 12.7cm, and the glass rod naturally sinks to: 3.5cm, with a little force to the end, soft heavy, lumpy.
200°C×120h	Liquid level height 13.0cm, with a little force to the end, soft heavy, lumpy.
200°C×168h	Liquid level height 13.1cm, with a little force to the end, soft heavy, lumpy.
210°C×72h	Liquid level height 13.0cm, with a little force to the end, soft heavy, lumpy.
210°C×120h	Liquid level height 12.7cm, with a little force to the end, soft heavy, lumpy.
210°C×168h	Liquid level height 13.2cm, with a little force to the end, soft heavy, lumpy.

5. Research and development of ultra-deep well leak prevention and plugging technology

The Permian tuff in The Platform basin area has low pressure bearing capacity and the basalt segment has developed fractures and pores, and the main leakage type is pore type. At the same time, affected by tectonic movement, the fracture leakage is easy to occur. In addition, the Ordovician is dominated by fracture-vuggy reservoirs, which are prone to large loss, and the corresponding loss types are mainly fracture-vuggy and cave-type [13]. At present, the main causes of loss in platform basin area come from four aspects: 1) When drilling the lower high pressure formation, the upper strata with lower bearing capacity are prone to well loss; 2) The formation encountered by drilling has multiple pressure systems, narrow safety window and poor stability of borehole wall; 3) The target layer is deep, the seismic resolution is low, the formation lithology changes greatly and the casing layer is many, the hole and casing clearance is small, the cementing equivalent density is high and easy to lose; 4) Plugging material will occur carbonization failure under high temperature conditions, leakage prevention and plugging effect is poor.

In view of the above problems, the corresponding plugging technology is optimized for different types of leakage in platform basin area. When the leakage is not serious, the use of conventional bridge plugging technology or cement plugging technology; LCC series high strength pressure plugging technology is used when high pressure capacity is required (>20MPa). NT series high strength pressure plugging technology is used when high temperature resistance is required (>240℃). FCL series high strength pressure plugging technology (>20MPa, 150℃) is selected if temperature resistance is required.

6. Ultra deep well cementing slurry improvement

The application of cementing technology in ultra-deep well is difficult and the technical application environment is complex, which puts forward higher requirements for cementing slurry performance [14][15]. The bottom hole temperature of class 8000m ultra-deep well exceeds 200℃, and the temperature resistance of cement slurry and cement stone is insufficient, which affects the safety of cementing operation and the integrity of cement ring seal. Conventional cement slurry admixture (retarder, water loss reducer, etc.) temperature resistance less than 200℃, high temperature sensitivity, poor compatibility, slurry thickening, water loss performance is difficult to ensure; Cement slurry settlement stability is difficult to ensure, cement stone high temperature strength recession is serious, integrity is difficult to ensure.

Aiming at the technical problem of ultra-high temperature in ultra-deep Wells in Tarim Block, a new type of high temperature resistant ultra-high density anti-gas channeling cement slurry system was developed. Based on the principle of particle size distribution, DRB-2S and DRB-3S were added to the system to improve the high-temperature strength stability of cement stones. The final cement slurry system has a temperature resistance of 210℃ and a density of 2.82g/cm^3.

Table 4. Performance table of new high temperature and high density anti gas channeling cement slurry system

ρ/g/cm^3	T/℃	Fluid Loss Additive /%	Retarder/%	$T_{thickened}$/min	P_{48h}/MPa	FL/mL	SPN
2.75	180	5	5.65	341	17.5	32	0.56
	190	2	3.65	270	16.9	32	0.18
	200	2	2.87	352	14.7	32	0.16
2.82	180	5	5	306	17.2	30	0.16
	190	2	5	366	15.2	30	0.17
	200	0	2.85	250	15	30	0.17

7. Conclusion

1) In response to various drilling and completion problems in the platform basin, Tarim Oilfield independently developed the TB-A well structure design, improved the TB-A and TB-B well structure design, and designed non-API casings to meet relevant strength requirements.

2) The current drilling fluid system in the platform basin area basically meets the requirements of 7000-8000m level drilling in the block, but the ultra-high formation temperature in the well section above 8500m leads to the poor effect of high-temperature and anti-collapse agent in the drilling fluid. The next step should be to improve the performance of anti - collapse agent.

3) In the basin area, three series of plugging agents, LCC, NT and FCL, are selected to solve the problem of leakage, which respectively need high pressure resistance, high temperature resistance and certain pressure resistance and temperature resistance. At the same time, in cementing leakage prevention and plugging, the development of a new type of high temperature resistant ultra-high density anti gas channeling cement slurry system, based on the principle of particle size distribution, adding high temperature reinforced material DRB-2S and anti-decay material DRB-3S to improve the high temperature strength stability of cement stone, to achieve high temperature resistance of 210℃.

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