

Drilling Engineering Design and Construction of Well Dong 11

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Abstract

The planned depth of well Dong 11 is 5,780 m, many complicated conditions may exist in the drilling process of this well, such as loose cementation and high risk of hole collapse in the upper formation, leakage of Cretaceous strata, caving mudstone in Jurassic, possible high-pressured saltwater zone and hydrocarbon zone in Sangonghe formation. In addition, this block is located in fault ruptured zone. Based on the above problems, casing program design, BHA design, drill bit selection, drilling fluid design and the cementing design was optimized and the drilling engineering design and site construction of the well was introduced. No complicated condition occurred during the whole well construction. PDC bit was used in the upper well section and PDC bit combined with screw drilling technology was used in lower well section, the average rate of penetration is 4.77 m/h, compared with the offset wells, the drilling speed increased obviously and the good hole diameter validates the serviceability of a strong inhibitive heat-resisting plugging polymer anti-collapse drilling fluid system in this area.

Key words: Drilling design; Casing program; Drill bit; Drilling fluid; Well Dong 11

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INTRODUCTION

Well Dong 11 is an exploratory well, located in northeast of Fukang City, Xinjiang Uygur Autonomous region, tectonic location is in well Dong 11 structural lithologic trap of eastern slope of Fukang sag in Junggar Basin. The main exploration targets are Qigu and Toutunhe formation of Jurassic system, the secondary target is Sangonghe formation. According to the offset well drilling and testing, the hydrocarbon shows is active in Toutunhe, Xishanyao and the second member of Sangonghe formation of Jurassic system, but differed widely in oil testing results. By drilling this well, the hydrocarbon condition of Qigu, Toutunhe and Sangonghe formation of Jurassic system is further understood.

The formations of this well drilled from top to bottom are expected to be Cenozoic group, Tugulu group of Cretaceous system, Qigu formation, Toutunhe formation, Xishanyao formation and Sangonghe formation of Jurassic system.

The actual drilling data of offset wells shows that the formation pressure is “normal-abnormal” distributed vertically. The pressure of this well gradually increases from about 4,900 m of Toutunhe formation, and reaches a peak at 5,540 m of the top Sangonghe formation, the maximum pressure coefficient is 1.55; The drilling fluid density of well Dong 6 in Sangonghe formation is 1.50 g/cm³, but the pressure coefficient is 2.06, which indicates that this well is high pressure and low permeability; In this formation of well Dong 7, Dong 8 and Dong 701 all drilled saltwater zone and high pressure oil and gas zone, the drilling fluid density reaches 2.00 g/cm³; Therefore, it may drill high-pressured saltwater zone and high pressure oil and gas zone in lower Sangonghe formation of Jurassic system.

The potential drilling risk factors are as follows:

(a) Low rate of penetration. It is easy to occur pipe sticking in the upper formation due to hole shrinkage, the strata is deeply buried, the lower formation has poor drillability, the collapsing and breaking of Jurassic mudstone, which will cause a long drilling cycle and downhole drill string accident easily.

(b) The formation near the fault plane is easy to break. The Cretaceous strata is in faulted fracture zone, wellbore stability is poor, it should enhance plug and prevent the stress collapse.

(c) The well cementing quality is hard to guarantee. Heat-resisting, pressure balancing, formation stabilizing and anti-channeling is difficult in liner cementing due to the high pressure and high temperature in Sangonghe formation.

1. DRILLING ENGINEERING DESIGN

1.1 Casing Program Design

The optimization of casing program design is the core of optimizing drilling technique, which not only concerns safety drilling, but also has a special significance for the improvement of drilling efficiency^[1-2]. In view of complex deep exploration wells, underground instance is complicated and inconstant, we can only get limited stratigraphic information, during the casing program design stage, both safety drilling and drilling cost should be taken into consideration^[3].

The casing program design of this well mainly used the experience of drilled wells in central IV region for

reference. From the results of pressure prediction, the pressure of Xishanyao and Sangonghe formation in Jurassic system is at a high level, we take into account of the complex situations drilled by adjacent wells and formation features of this well, and adopt three layer casing program, the basic ideas are as follows:

(a) The $\Phi 508$ mm conductor seated at 50 m is to isolate the surface loose soil and establish the well head.

(b) The $\Phi 339.7$ mm surface casing with 1,500 m deep is to create favorable conditions for the drilling of second spud.

(c) The $\Phi 244.5$ mm intermediate casing with 4,650 m deep which is drilled by $\Phi 311.2$ mm drill bit is to isolate easily collapse and break of Tugulu group and seats in target zone of Qigu formation, provide guarantee for drilling the lower reservoir, and the cement slurry returns to 1,300 m.

(d) The $\Phi 139.7$ mm production liner down to the bottom-hole which is drilled by $\Phi 215.9$ mm drill bit is suspended at 4,450 m, the cement slurry returns to the liner hanger. If high pressure hydrocarbon zone is encountered, casing should tieback to the wellhead in the third spud. The position of the casing should be corrected according the actual drilling.

(e) If hydrocarbon indication in Toutunhe formation is good or high pressure formation is drilled in lower well section, $\Phi 177.8$ mm casing should be run in advance and then $\Phi 149.2$ mm drill bit should be used to TD.

The casing program design of well Dong 11 is shown in Table 1.

Table 1
The Casing Program of Well Dong 11

Spud	Bit size (mm)	Drilling depth (m)	Casing OD (mm)	Casing setting depth (m)	Top of cement (m)
Conductor	660.4	0-51	508	50	Surface
First spud	444.5	51-1,501	339.7	1,500	Surface
Second spud	311.2	1,501-4,652	244.5	4,650	1,300
Third spud	215.9	4,652-5,780	139.7	Liner (4,450-5,777)	4,450

1.2 BHA Design

Deviation control of straight holes in the petroleum well drilling is a long-term perplexed technical problem, which is a factor of constraining drilling operation, reducing cost and increasing benefits^[4]. In order to ensure wellbore quality, deviation-controlled straight drilling technology is adopted, the corresponding drilling parameters should be adjusted timely according to the variation of formation. Tower BHA is designed in conductor section, pendulum BHA is used in the first spud to ensure the upper well vertical, and lay the foundation for construction in the lower easy deviation strata; Four hole assemblies is designed in the second and the third spud, including

tower BHA or conventional BHA, pendulum BHA, screw drilling tool and torsional impact drilling tool.

In order to enhance hydraulic parameters, bottom-hole and wellbore purification capacity, it is necessary to minimize the use of $\Phi 127$ mm internal upset drill pipes, $\Phi 139.7$ mm internal flush drill pipes is designed in $\Phi 311.2$ mm hole. PDC combined with screw drilling technology or torsional impact technology is adopted according to formation in lower well section, to reduce the rotary speed and WOB in the drilling process and drilling tool load, meanwhile, improve preventive inclination of the entire drilling tool.

1.3 Drill Bit Design

According to the drillability of the strata and offset well formations, the bits with more footage, high ROP and normal wear is selected. Milled-tooth bit with high ROP is used in upper soft formation. Insert bit with more footage is adopted in the deep well section. For the bit selection,

based on the offset references, actual drilling and bit characteristics, suitable drilling parameters is optimized.

Figure 1 shows the analysis of the average penetration rate in different strata of offset wells. Figure 2 shows the maximum drilling footage of offset PDC bit at different formations.

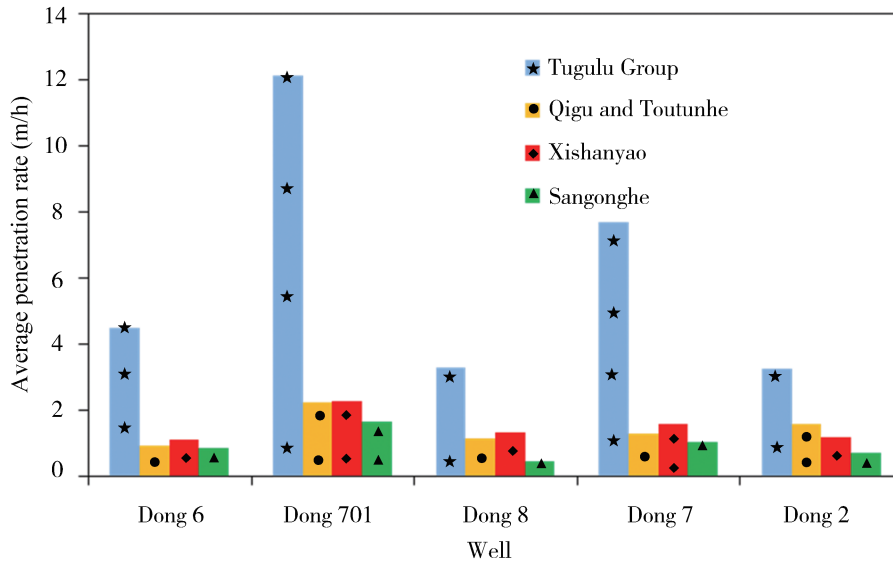


Figure 1
 Average Penetration Rate of Offset Wells

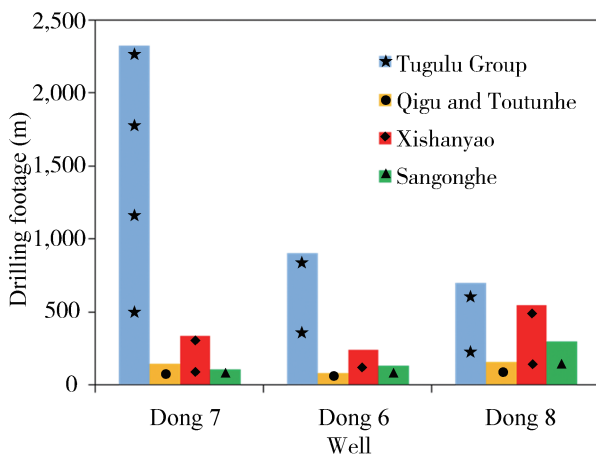


Figure 2
 Drilling Footage of Offset PDC Bit

Refer to the relevant information of drill bits in adjacent wells, the characteristics of formations and practical experience, 17 drill bits are designed, including 9 cone bits and 8 PDC bits, the drill bit design is shown in Table 2.

Table 2
 The Drill Bit Design of Well Dong 11

Formation	Bit size (mm)	Bit type	Quantity	Well section (m)
Cenozoic Group	660.4	P2	1	0-51
Cenozoic Group	444.5	HAT127	1	51-1,501
		HJ537	1	
~Qigu Formation	311.2	MD517	3	1,501-4,652
		PDC	4	
~Sangonghe Formation	215.9	MD537	3	4,652-5,780
		PDC	4	

1.4 Drilling Fluid Design

The principles of drilling fluid in this well are beneficial to environment protection and good for discovering and protecting oil and gas reservoirs, geological data admission, fast and safety drilling, oil removal and gas exhaust, prevention and treatment of complicated situations.

1.4.1 Drilling Fluid System Design

In the upper layer, mudstone is easy to cause hydration expansion, mud making is also serious, the sandstone is of loose cementation and high permeability, which is easy to form thick mud cake and cause pipe sticking, the rigid and fragile shale in the lower layer is easily to slough^[5]. The prevention of collapsing and sticking in Cretaceous strata should be paid more attention; It may drill high-pressured saltwater zone and high pressure oil and gas zone in Sangonghe formation of Jurassic system, we should pay attention to control the density of drilling fluid to

prevent blowout in the drilling process. The temperature in lower formation of this deep well is high, the drilling fluid should maintain inhibition, anti-collapse, anti-pollution, high temperature resistance, and good rheology. Meanwhile, to ensure drilling safely and quickly. It is necessary to keep low water loss in reservoir interval and effectively protect reservoirs.

According to the characteristics of the formation drilled and construction of adjacent wells, the drilling fluid system design is shown in Table 3.

Table 3
The Drilling Fluid System of Well Dong 11

Well section (m)	Formation	Drilling fluid system	Drilling fluid density (g/cm ³)
0-51	Cenozoic Group	Bentonite slurry	1.08-1.10
51-1,501	Cenozoic Group	Polymer drilling fluid	1.05-1.10
1,501-3,700	Cenozoic~Tugulu Group	Strong inhibitive polymer anti-collapse drilling fluid	1.10-1.25
3,700-4,500	Tugulu~Qigu Formation	Strong inhibitive plugging polymer anti-collapse drilling fluid	1.20-1.30
4,500-4,652	Qigu Group	Strong inhibitive plugging polymer heat-resisting and anti-collapse drilling fluid	1.20-1.30
4,652-5,780	Qigu~Sangonghe Formation	Strong inhibitive heat-resisting plugging polymer anti-collapse drilling fluid	1.30-1.90

1.4.2 Maintaining Measures of Drilling Fluid

In the upper Cenozoic group, the lithology is soft mudstone and sandy mudstone intercalated with some unconsolidated clay. The formation is poor diagenetic grade, loose stratum. Hole shrinkage due to hydration swelling may lead to hard trip. The drilling fluid must have strong cutting carrying capacity and fine stability of borehole due to high ROP and high concentration of annular drilling cutting.

It will drill the lower Cenozoic group, Tugulu group of Cretaceous system and the upper Qigu formation of Jurassic system in the second spud, the rock types are mainly claret, brown-red, brown, maroon mudstone and sandy mudstone which may lead to well collapsing and breaking; It should prevent leakage, erosion, breaking, sticking and collapsing in Cretaceous system. The pressure of this section is normal based on pressure prediction, drilling fluid should have strong inhibition ability to ensure the properties of wall building, anti-collapse, good rheology and good wellbore stability^[6].

It will drill the lower Qigu group, Toutunhe, Xishanyao and Sangonghe formation in the third spud which are hydrocarbon reservoirs, it should prevent inrush of oil and gas, blowout, leakage, sticking and protect oil and gas reservoir. Anti-collapse in Xishanyao formation should be noticed because it contains black coal seam and dark gray carbon mudstone. This well section is near the fault, the

formation is possible broken and the wellbore stability is poor, so it should raise the mud weight with the increase of well depth to balance formation stress, in addition, ensure the dosage of anti-sloughing agent, and prevent collapsing and sticking. The average borehole enlargement rate for the third spud in well Dong 6 is up to 34%; The drilling fluid density is high, according to the on-site shows and pressure monitoring adjust the density timely, weigh uniformly to prevent formation breakdown and reservoir contamination; The down hole temperature is high, supplement anti-high temperature agent and organic silicon stabilizer according to the well temperature. During drilling, observe the mud return, drilling cuttings and shape change in the shale shaker, borehole stability protection and monitor work should be done well to avoid severe borehole sloughing. The API filtration should be controlled to less than 4 ml and HTHP filtration should be less than 12 ml for reservoir protection.

After drilled to the TD, the sticky drilling fluid is selected to carry cuttings and make a short trip to ensure hole smooth and the mud density before pulling out can balance the downhole high pressure layer. A special sealing slurry with 3% of lubricant and 2% of anti-collapse agent is designed before tripping out to seal the open hole section and ensure the success of electrical logging and casing running.

1.5 Cementing Design

1.5.1 Technical Difficulties of Cementing

The sealed section for intermediate casing with large diameter is long and it requires large amount of cement.

The temperature and pressure are high for the liner cementing, it is difficult for pressure stabilizing and anti-channeling.

1.5.2 Technical Measures of Cementing

Two-stage cementing method is adopted. Plastic cement slurry system is designed in the first stage cementing, for the second stage cementing, fly ash cement with low density is used in the upper section and the conventional cement slurry is used in the lower section.

High temperature resistant and anti-channeling cement slurry system is adopted to ensure cementing quality of objective interval.

Table 4
Basic Cementing Parameters of Well Dong 11

Item	Casing shoe (m)	Top of cement (m)	Cementing method	Remarks
Riser	50	Surface	Interpolation	
Surface casing	1,500	Surface	Conventional	Double-stopper
Technical casing	4,650	1,300	Two-stage	The position of stage collar is about 3,200 m
Production liner	5,777	4,450	Liner	Liner hanger with packer

2. DRILLING CONSTRUCTION

Well Dong 11 spudded in August 7, 2015 and finished well in November 25, 2015. The actual total depth is 5,193 m, the average ROP is 4.77 m/h. The actual construction was conducted in strict accordance with the casing program design, the inhibitive plugging polymer anti-collapse drilling fluid system was used in concentrated mudstone section, when entering the hydrocarbon bearing zone, the strong inhibitive heat-resisting plugging polymer anti-collapse drilling fluid drilling fluid system was adopted, which can control the hole enlargement and shrinkage effectively. The use of mature PDC combined with screw drilling technology in the second and third spud increased ROP compared with conventional drilling assembly.

CONCLUSION

PDC bit is used as soon as possible in the first spud, which can increase the ROP and save cost.

The optimization of BHA and drill bit plays an important role in increasing the penetration rate and shortening drilling cycle. PDC combined with screw drilling technology is used in the lower section which can reduce the rotary speed and the collision of drilling tool to the wall.

The result of field operation indicates that drilling fluid performance should be adjusted according to the formation. It can effectively ensure the drilling fluid with

good carrying cuttings, inhibition, plugging property and borehole stability, it obtains a very good effect.

It is more difficult to control the falling cuttings, which influences the service life of screw and increases the tripping time and underground risk. The performance and formula of drilling fluid should be adjusted in advance to stabilize the borehole wall, hole cleaning should be done as far as possible to prevent complicated accidents.

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