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The Research and Application of Low Density Cement Slurry System at Low Temperature in Daqing Oilfield

YU Dongnian[a],*

[a]The Drilling Technique 1st Company of Daqing Oilfield, Daqing, China.
*Corresponding author.

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Abstract

During long sealing cementing of low temperature shallow gas well in Daqing oilfield, for the low density cement slurry at low temperature, the setting time is longer, gelling strength development is slower, filter loss is greater and the anti-channeling ability is weak. It would make the happening of annular gas channeling and fluid emitting, affect the cement job quality. Low density low temperature anti-channeling cement slurry system was studied with compound early strength agent, polyacrylate polymer latex drop loss of water, dispersed polymer powder anti-channeling agent, improve the comprehensive performance low density cement slurry. Laboratory experiments showed that setting time shortened by 50%, early strength increased by 46%, permeability decreased by 50%, interfacial bond strength increased by 47%, compared with the low density cement and the class G well cement. The application tests in the field were carried out in 18 wells. High-quality rate of well cementing increased by 11.1 percentage points. The incidence rate of fluid emitting is decreased by 1.6%. This cement slurry system can satisfy the requirements of cementing operation. It will improve the cementing quality of long sealing section in a shallow layer in Daqing Oilfield.

Key words: Low density; Low temperature; The anti-channeling ability; Cement slurry; Cementing quality

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INTRODUCTION

There are many blocks such as shallow gas and gas cap gas reservoir from south to earth in Daqing oilfield, which are at 100-800 meters. Parts of the shallow gas have been shot up to over 100 meters of the hole section, some oil/water wells have the leaky layer, high pressure layers, shallow gas layer at the same time.[1] The accidents such as blowout and fluid emitting have happened many times during the well drilling process. Low density cement slurry have been used to seal the upper shallow gas layer in order to reduce the risk of drilling and completion as well as well control difficulty. Low temperature shallow cementing quality is difficult to guarantee due to the influence of long low cement stone jelling time, slower development rate of early strength and poor channeling prevention performance as well as low interfacial bond strength when the temperature is under 30℃.[2-3] So the accidents such as oil/gas water invasion and fluid emitting happened frequently during the cementing operation and follow-up operations. According to statistics, the incidence reached 26.3% of shallow gas wells in south of SaNan block. It increases the pressure on safety and environmental protection, as well as affects the development of oilfield.

Low temperature is the biggest problem for the low density shallow cementing, it delays the hydration of cement, which affects the compressing strength of the cement stone especially its development of early strength. A lot of researches has been published on low temperature high early agent, filtrate reducer and anti-channeling at home and abroad, but there are few adopt to low or ultra-low temperature cement slurry system. These cement slurry systems almost ignore the jelling time of cement slurry, initial and final jelling time is too long, and the most dangerous moment of fluid channeling always occured during the initial and final jelling time of cement slurry.[4-5] So compound early

strength agent is adopted to shorten jelling time and improve the early strength of cement stone. Polyacrylate polymer latex filtrate reducer is also adopted to control the filter loss of cement slurry, it solves the problem of filtrate reducer super-retardation at low temperature. Dispersible polymer powder anti-channeling is adopted to improve channeling prevention performance of cement stone, and enhance the cementing strength of cement mantle boundary, as well as improve pack ability of shallow gas layer, guarantee the quality of well cementation, even prevent cross flow and fluid emitting after well cementing.

1. THE RESEARCH OF LOW DENSITY ANTI-CHANNELING CEMENT SLURRY AT TEMPERATURE

1.1 The Composition of Low Density Cement

According to the geology situation and drilling design requirements of adjustment wells in Daqing oilfield, low density cement (the density is 1.60 g/cm^3) is adopted to cementing, low density characteristics of admixture and some lightweight materials which have gelatination are used to realize the low density of cement, it consists mainly of coarse silicon (fly ash), tiny micro silicon.[6]

1.2 The Research of Low Temperature Early Strength Agent

For the following questions, early strength agent's effect is not obvious at low temperature, the later strength of cement rock always decline, cement rock shrink. Compound early strength agent which is consist of silicate and amine organic matter have been adopted. The principle of multiphase acceleration and disperse solubilization is used to improve ionic strength of cement slurry system and enhance the active intensity of alkalinity slurry as well as increase the calcium sulfoaluminate amount of cement depending on different functional group of each component. Based on the above results, early cement frame is formed during the process of growth, C-S-H jell and the other hydrate product keep filling and curing, the jelling time of cement is shorten and the strength in the early stage is improved obviously.[7] We compounded the early strength agent by the method of permutation and combination, the formula of early strength agent A:B:C:D=5:2:1:1 was determined at last, the experiment was carried out to evaluate the performance, The experimental results are shown in Table 1.

Table 1
The Experimental Data Table of Early Strength Agent Performance Evaluation

Early strength agent dosage %	Compressing strength (Mpa) 10℃×24h	27℃ jelling time (min) initial setting/final setting
0	0.4	515/58
2.5	1.2	435/55
3.5	2.3	360/50
5.5	4.6	205/35

We can get from the experiment that the early compressing strength of cement stone increased with the increasing of early strength agent, at 5.5% the compressing strength increased by 4.2 MPa, initial jelling time is shortened to 205 min, final jelling time is shortened to 35 min, the performance of cement slurry is stable and satisfy the requirements of cementing operation.

1.3 The Research of Low Temperature Filtrate Reducer

In the case of filter loss is large during the waiting on cement, the cement ring volume shrinkage induce the shallow gas channeling, filtrate reducer is super-retardation at low temperature, polyacrylate polymer latex filtrate reducer is adopted to inform cross linked network by macromolecular chain copolymerization,[5] it binds the free water of cement slurry, control the filter loss of cement slurry and prevents the shrink of cement mantle at last. At the same time, unsatisfied chemical bond of methacrylic acid is used to bridge with the cement gelatin, it shortens the firm time and avoids the super-retardation of filtrate reducer at low temperature. The experiment is based on the increase of low temperature early strength agent dosage by 4.5%, the experimental results are shown in Table 2.

Table 2
The Experimental Data Table of Filtrate Reducer Which Is Added Low Density Cement Slurry

Filtrate reducer dosage %	Thickening time (min) 38℃×15.9MPa	27℃ jelling time (min) initial setting/final setting	Filter loss (mL) 45℃×6.9MPa
0	224	235/35	400
5	226	230/33	140
8	226	227/32	48
10	228	225/30	34

We can get from Table 3 that filter loss of cement slurry decreased obviously with the increased of filtrate reducer dosage. The filtrate reducer has no effect on thickening time and jelling time, filter loss of cement slurry is less than 50 mL when filtrate reducer dosage is greater than 8%. Low temperature filtrate reducer has good compatibility with low temperature early strength agent.

1.4 The Research of Low Temperature Anti-Channeling Agent

The dispersed polymer powder is used as the anti-channeling agent to improve the anti-channeling performance of cement stone. It is adsorbed on the surface of cement particle by deposition of polymer particle and electrostatic effect, bonded into parcel shape solid with cement hydrate, improving the structure of cement stone.[5] The stable flexibility and elasticity proofed cellophane is formed in the micropores of cement matrix materials, improving the flexibility and elasticity of cement stone, as well as decreasing the permeability of cement stone, the effect of anti-channeling is realized. At the same time, the polymer powder contains lots of polyvinyl alcohol, have good bonding performance, the transition zone structure of cement ring interface and bonding strength as well as weak interface phenomenon can be improved.[8] The isolation ability of shallow gas layer is also improved at last.

The evaluation experiment is based on the addition of low temperature on early strength agent dosage by 4.5% and decrease filtrate reducer by 8%, the addition of anti-channeling agent is chosen as 3% at last. With the increase of anti-channeling dosage the permeability of cement stone is decreased, The low temperature anti-channeling agent has good compatibility with the system. At the same time, the evaluation experiment results of permeability and interface strength under different temperature are presented in Table 3 and Table 4.

Table 3
The Experimental Data Table of Cement Slurry Permeability

Name	Permeability ($\times10^{-3}\mu m^2$)					
	27℃×24h	27℃×48h	27℃×15d	45℃×24h	45℃×48h	45℃×15d
Low density puree	0.1936	0.1564	0.1247	0.1762	0.1564	0.1127
Low density and temperature anti-channeling cement slurry	0.0956	0.0836	0.0735	0.0844	0.0721	0.0532

It is concluded from Table 3 that the low density and temperature anti-channeling cement slurry system has low permeability at low temperature. Compared with the original pulp, the permeability of low density and temperature anti-channeling cement slurry decreased by 50%, it is helpful to prevent the happening of fluid emitting.

Table 4
The Experimental Data Table of Interface Cementing Strength

Name	Interface cementing strength (MPa)		
	10℃×48h	27℃×48h	45℃×48h
Low density puree	0.198	0.212	0.251
	0.227	0.253	0.273
Low density and temperature anti-channeling cement slurry	0.304	0.313	0.332
	0.316	0.338	0.394

It is concluded from Table 4 that the low density and temperature anti-channeling cement slurry system has good interfacial bond strength. Compared with the original pulp, interface cementing strength of 27℃×48 h increased by 47%, it is helpful to improve the sealing quality of low temperature shallow layer.

1.5 The Evaluation of Low Density Anti-Channeling Cement Slurry System at Temperature

In order to satisfy the requirements of low temperature shallow well cementing, low density and temperature anti-channeling cement slurry conventional performance under different temperature is evaluated. The experimental results are shown in Table 5.

According to Table 5, cement slurry performance can satisfy the requirements of cementing operation when low temperature and temperature anti-channeling cement slurry system at low temperature. Compared with the original pulp, the system has higher early strength, the compressing strength of 27℃×8 h is increased by 50%, it has faster jelling time, the jelling time shortened by 46%, has lower filter loss. It is helpful to improve the cement job quality of low temperature shallow wells and prevent the happening of fluid emitting.

Table 5
The Experimental Data Table of Low Density and Temperature Anti-Channeling Cement Slurry Conventional Performance Under Different Temperature

Temperature (℃)	Cement slurry system	Thickening time (min)	Compressing strength (MPa)		Jelling time (min) initial setting/final setting	Filter loss (mL)
			8h	24h		
10	Puree system	——	0.2	0.4	500/65	≥400
		——	0.8	4.3	265/48	49
27	Puree system	245	1.4	4.3	480/60	≥400
		237	2.1	5.1	255/45	48
38	Puree system	238	1.9	5.2	445/50	≥400
		226	3.2	8.6	230/33	36
50	Puree system	213	2.5	16.7	405/45	≥400
		182	4.1	17.9	212/30	32

2. THE FIELD TEST

2.1 Block Situation and Geology Difficulties of Test Site

There are more than 50 fault developments in PuNan block, the amplitude is almost 10-50 m, the drilling wells are easy to leak on both sides of the fault. The high pressure layers are concentrated distribution in Pu-1 and the maximum pressure coefficient is 1.71, the minimum breakdown pressure coefficient is 1.27-1.38. The local reservoir pressure is too high and not easy to stabilize which may make oil-gas water intrusion easily and fluid emitting after well cementation. Heidimiao block belongs to shallow gas development. Under the condition of low temperature 30℃, the sealing quality of gas horizon gas horizon is poor, cement job quality is difficult to guarantee, the phenomenon of fluid emitting would be happened easily after cementing. In the past, 25 wells have been drilled, four wells have appeared, the incidence rate is 16%.

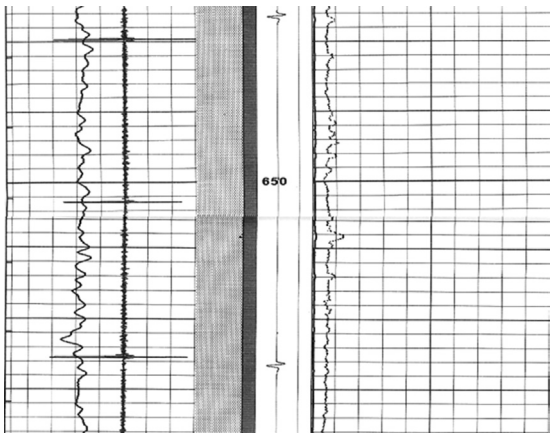

Figure 1
Pu-110 Well Acoustic Amplitude

2.2 The Field Test Situation

Low density anti-channeling cement slurry is adopted to seal the high pressure reservoir, low density and temperature anti-channeling cement slurry is used to seal the shallow gas layer at the top, temperature anti-channeling cement slurry primary pulp is used in the following.[10] The cement slurry system was carried out in 18 wells which are complex and difficult in the field test, the results shown that high-quality rate of well cementing is 72.2%, the qualification rate is 100%, the fluid emitting doesn't happened in application wells. Compared with the conventional controlling wells, the high-quality rate of well cementing is increased by 11.1%, the incidence rate of fluid emitting decreased by 1.6%. For example, total depth of Pu-110 well is 1,010m, the combination model that low density and temperature anti-channeling cement slurry + low temperature anti-channeling cement slurry is applied to cement, cement job quality is high, there is no fluid emitting phenomenon. The cement job quality is shown in Figure 1.

The field test were shown that low density and temperature anti-channeling cement slurry system can prevent the happening of annular gas breakthrough and fluid emitting at low temperature effectively, as well as improve the cement job quality. The cement job quality statistical list of application wells is shown as follows.

CONCLUSION

(a) Compound early strength agent of silicate and amine organic, polyacrylate polymer latex filtrate reducer, as well as disperse polymer powder anti-channeling agent, which are chosen by the theoretical analysis and experimental methods all have good compatibility, it determines the formula of low density anti-channeling cement slurry system at low temperature.

(b) Low density anti-channeling cement slurry system at low temperature have the characteristics of short condensation time, high strength in earlier times, low permeability as well as high strength of interface cement under low temperatures, all these characteristics are satisfied the requirement of low temperature shallow gas long sealing cementing.

(c) It is shown by field test that low density and temperature anti-channeling cement slurry system can improve the cement job quality of high pressure layer and prevent the happening of fluid emitting after shallow gas wells cementation.

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