Casing Damage Prevention and Control Technology of Super Heavy Oil Thermal Production Well

A Case research of Du 84 block in Shu 1 area, Liaohe Oilfield

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***Abstract*—A large number of thermal recovery wells casing was damaged during the early development of Du 84. Casing damage thermal production wells amounted to 214 by the end of 2002, accounting for 66.7% of the production wells. The casing damage had affected the normal production of these thermal wells. Thus casing damage mechanism and casing damage prevention were key issues in Du 84 thermal production wells. Through investigations and researches, reasons for the initial casing damage were determined as follows: higher thermal stress, sand production in oi1 wells, unfit sub with API round thread and bias buttress thread, and improper heat insulation tubing and heat insulation measures. In order to reduce the casing damage rate caused by the factors of thermal stress and low casing strength Etc., the related measures adopted are: pre-stress pulling completion, substituting N80 casing with bias buttress thread for the common casing, using special cement for thermal production wells and returning to the surface, and utilizing fine heat insulation tubing. After the management, the casing damage in therma1 wells was decreased, but the initia1 casing damage was stil1 heavy. Thus new techniques were adopted: reducing the casing stress during steam injection using heat stress compensate tool, increasing the deformation resistance using TP100H casing, and solving hoop stress problems of production casings caused by sand production and perforation using TP120TH external upset casing. Through the long-term researches and practices, the initial casing damage rate of therma1 wells was reduced, which ensure the effective development of Du 84 super heavy oil with steam stimulation method and SAGD development mode conversion.**

Keywords- super heavy oil; thermal production; completion; casing design

I. INTRODUCTION

Du 84 located in the middle of Liaohe western slope, Du 84 is an axial North East, structural nose, which reservoir buried depth is from 550 to 1150 m, with reservoir properties of medium-high porosity and extra high permeability. The crude oil density is 1.001g/cm^3 at 20 ° C, and gas free crude oil viscosity is 16.8×l0^4 mPa.s at 50 ° C, thus, Du 84 is a super heavy oil reservoir, as in [1-2]. The thermal recovery wells casing of Du 84 ultra heavy oil reservoir was serious damaged since the development of 1996 with thermal recovery method. Casing damage thermal production wells amounted to 214 by the end of 2002, accounting for 66.7% of the production wells. Thermal recovery wells casing damage near packer to the reservoir accounted for 64.42% of the total casing damage wells. Casing damage included three forms of casing deformation (accounting for 46.4% of the total casing damage wells), tube dislocation (accounting for 23.3% of the total casing damage wells), screwed nipple leakage and release(accounting for 16.4% of the total casing damage wells).

II. CASING DAMAGE CAUSES OF DU 84 THERMAL RECOVERY WELLS

A. Heat Stress

The steam stimulation method was used in the early development of Du 84, and the typical well structure of the thermal recovery wells shown in Fig. 1.

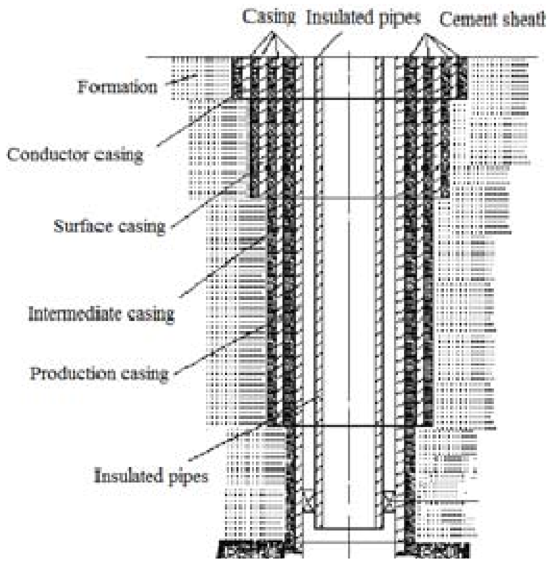

Figure 1. Typical steam injection thermal recovery well structure diagram

During the steam injection, the average temperature of steam injection is about 340°*C*, some nearly 400°*C* (General steam injection pressure more than 12MPa, some up to

17MPa), more than the maximum temperature allowable range of API N80 casing(204-220°*C*).From Table 1, N80 casing mechanical performance was significantly worse at a high temperature. N80 casing yield strength decreases by about 18%, elastic modulus decreases by approximately 38%, tensile strength reduces by 7% due to high temperature (340°*C*), as in [3].

TABLE I. N80 CASING MECHANICAL PROPERTIES AT HIGH TEMPERATURE

Temperature °*C*	Decreasing proportion of yield strength %	Decreasing proportion of elastic modulus %	Decreasing proportion of tensile strength %
340	18	38	7
400	25	45	25

Laboratory experimental results and theoretical results show that the maximum stress of thermal recovery process casing suffered more than 700MPa, which is more than the strength limit of the N80 casing strength values 552MPa. Ordinary N80 casing will yield plastic deformation at high temperature which may lead to casing damage, as in [4-9].

The casing deformation relaxation affects the sealing performance of the casing collar. The universal round and buttress thread temperature limit is below 300°*C*. Thus, Exceed the tolerances in the role of high-temperature axial load, radial deformation of the coupling and casing threads, combined with the buckle is not tight can cause leaks and release. On the other hand, the greater the residual stress, the worse the well conditions and casing properties. The survey shows that the first seven steam injection cycles, casing damage accounted for 81.7%. Casing damage accounts for about 35.4% in the first three steam injection cycles. After the third steam injection cycles, the residual stress will reach the yield limit of N80 casing.

B. Sand Production

Casing stress uneven causing by sand production will affect the life of the casing, resulting in the casing damage. The ratio of casing damage will increase with the increase of well sand production. When the number of sand washing reaches to 6 times, casing damage ratio will reach 100%, (Fig. 2).

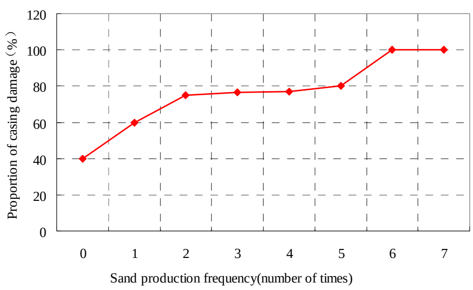

Figure 2. The relationship of sand production number and casing damage ratio of thermal production well.

III. THERMAL RECOVERY WELLS CASING DAMAGE PREVENTION PROCESS

A. Pulling Pre-stress

The basic principle of the casing pulling pre-stress is to apply initial casing stress, to offset the large thermal stress during steam stimulation. Liaohe Oilfield started pulling pre-stress work from the 1980s, since the mid-1980s, all thermal recovery wells had used pulling pre-stress completion. The pre-stress methods include two-setting cement pulling pre-stress, hollow ground spear pulling pre-stress and other technologies.

B. Using N80 Buttress Thread Casing to Replace the Ordinary Casing

Ordinary J55 round thread casing was used when the Liaohe oil field began production of heavy oil, which resulted in extensive damage to the casing. Learn from foreign experience in heavy oil recovery, N80 buttress thread casing was used (although buttress thread casing seal is difficult to meet the thermal recovery requirements, but its intensity is relatively high). Before 1999, all the wells were N80 casing completion of Du 84 , and carry out field test of N80 + P110 casing combination completion.

C. Using Special Thermal Recovery Cement

It will easily generate casing damage above the cement surface if cement did not return to the wellhead, and will generate casing extend, sometimes casing will extend more than 2m, which will cause inconvenience to the construction and, more importantly, causing casing damage. Therefore, it is required that the cement return to the wellhead of thermal production wells.

D. Using Well-insulated Tubular

Research and theoretical studies have proved that the heat insulation pipe insulation directly affect the thermal stress of well casing. The main factors that affect the insulating effect of the insulation tube are insulation performance of insulated pipe, the link sealing performance, and other process conditions. The first introduction of the Liaohe Oilfield is common insulated tubular, insulation performance is not very good. After development of vacuum insulated tubing, the insulation performance has been greatly improved. Now efficient insulated tubular has been used in Du 84.

IV. PREVENTION CASING DAMAGE MEASURES

After taking these measures, DU 84 thermal recovery casing is still serious damage. Early period casing damage rate reach 66.7% in 2002.

Analysis show that early period casing damage causes are as follows.

- Pulling pre-stressed is not enough. Calculation show that about 100t pulling strength is needed, coupled with the casing weight, required pulling pre-stress is bigger, but drilling rig pulling strength is limited.
- The actual pulling pre-stressed ground anchor will failure easily due to the shallow, not good

cementation heavy oil reservoir. So often occurs all casing been pulling out, and can not achieve the purpose of pulling pre-stressed.

- Most of the wells of Du 84 are directional wells, so it is difficult to ensure that the pulling pre-stressed spread to the reservoir segment casing parts.
- Du 84 thermal production wells in the wellhead is generally circular iron requirements completion, casing head just at the wellhead, but actually very difficult to achieve the casing collar just at the wellhead, results pulling pre-stressed only the casing coupling referred to the wellhead.
- The steam injection temperature reaches 350°*C*, the casing at a high temperature thermal stress reaches 700MPa or more, exceeding the N80 casing can withstand the thermal stress intensity limit.
- The aforementioned measures are on the improvement of the thermal stress, but the investigation show that sand production also will cause casing damage corresponding. Reservoir segment of the thermal recovery wells casing collapse weak is also one of the reasons of shorten casing life.

A. Application of Thermal Compensator

Changes in the thermal stress generated in the thermal recovery wells steam injection process, the production casing will have a small amount of stretching, which is the main reason for casing damage. Completion, the installation of a thermal stress in a certain position of the reservoir the upper compensator can compensate for the production casing of this micro telescopic, to achieve the purpose of protection casing. Fig.3 is the schematic diagram of thermal stress compensation, high-temperature high-pressure bellows sealing elements, the upper and lower end of the components were welding on the top ring and bottom ring, in order to prevent the center tube and limit connections to go down when the axial displacement, in the meantime equipped with a round, flat key, to ensure that they can only produce a certain amount of external force up and down movement. Thermal stress compensation in the bellows sealing elements in the well in its original state, when the force from the direction of the short section of pipe up to produce the movement, bellows began to elongate, on the contrary were compressed.

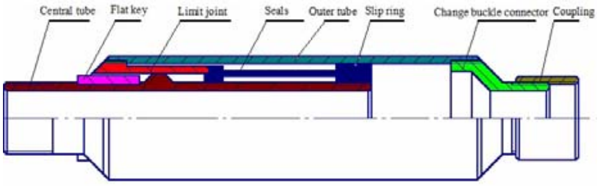

Figure 3. Thermal stress compensator schematic.

B. Using TPl00H Type Casing

Theoretical studies and laboratory experiments have shown that thermal recovery wells casing thermal stress is much higher than the intensity value of the N80 casing. The ultimate solution to the casing damage, the best way is to select the better casing, as in [10].

TPl00H made of alloy steel, fully meet the requirements of API standard on some of the parameters of the casing steel. The experiments show that in the same load conditions, the N80, casing displacement significantly large than TP100H casing, the displacement of the same or similar conditions, the load values the TPIOOH casing can withstand significantly higher than the N80 casing.TP100H casing yield strength is 720-920MPa, at least can withstand the thermal stress of 73lMPa, while N80 casing yield strength is 552-758MPa, it will yield a larger deformation at 570 MPa. The tension and compression testing reflect TP10OH casing deformation is small compared to N80 casing. From the analysis of thermal stress, tension and compression cycle, a large deformation, especially under high temperature and high stress conditions, the N80 casing deformation is much larger than TP100H casing, which direct results it residual stress at room temperature is also higher (up to 573MPa), while TP100H casing is only 343MPa.So, the TP100H casing is more suitable for thermal recovery wells.

C. Using TP120TH External Upset Casing

DU 84 thermal production wells in the application of new casing TP100H and thermal stress compensator, the casing pre-damage rate decreased significantly, but the damage rate is still greater, because of its steam injection intensity is relatively high, and especially the sand production is serious. Extensive sand control measures had been taken in the actual production, but sand production will cause uneven force, which resulted in the casing collapse. Application of thermal stress compensation reduces the axial stress of the casing, but it does not have a large effect to the casing damage caused by the large and uneven axial pressure due to axial stress.

Mechanism analysis showed that the casing wall thickness, can better withstand the uneven loads, and thermal stress damage to the casing, so the TP120TH casing pilot test was done. In accordance with API standard Casing link to determine TP120TH external upset casing specification 193.7mm×17.14mm. Detection by Xi'an pipe center, the collapse strength of TP120TH is 138.1MPa, while the TP100H casing collapse strength is 41.51MPa. Thus, at room temperature TP120TH external upset casing collapse strength is much larger than the TP100H casing; 350°*C* high temperature conditions, TP120TH yield strength is 878MPa, which is 32% more than TPl00H.The TP120TH external upset casing under high temperature anti-collapse strength was significantly higher than TP100H casing.

Select the 11 directional wells tested in 2003, the casing program as shown in Fig.4.

Guide + one TP100H casing + choke ring + one TP100H casing + convert casing (TP100H steel grade) + several TP120TH casing + convert casing (TP100H steel grade) + thermal stress compensator + several TP100H casing (up to well head).

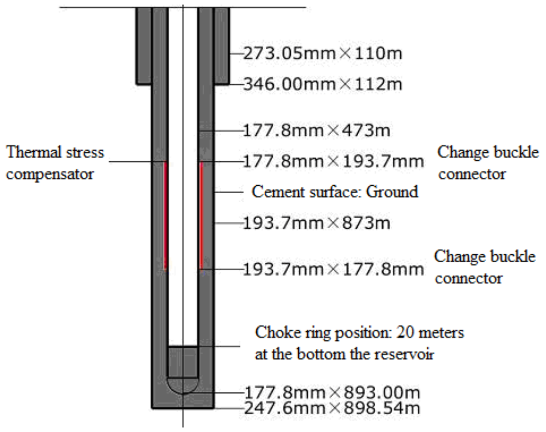

Figure 4. Casing Program of External Upset Casing.

The test results show that using thicker casing TP120TH outside can significantly reduce the uneven casing load caused due to down hole sand production and other reasons, effectively prevent the casing damage. 11 oil wells in the stage production of the pilot test area is normal, the average production of 5.1 no casing damage occurs (Fig. 5).

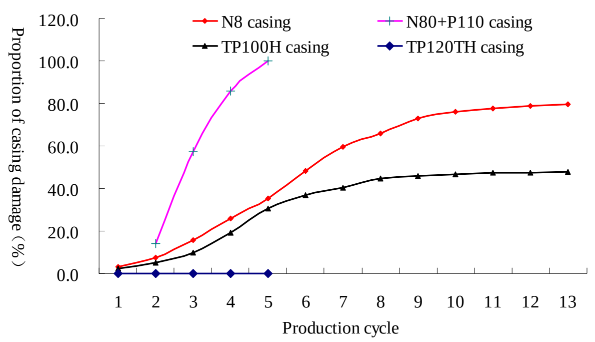

Figure 5. Casing Program of External Upset Casing.

V. Conclusions

- There was a high casing damage proportion during the early stage development of Liaohe oilfield Du 84.
- Casing damage caused mainly due to thermal stress in the steam injection process, the production process of sand.
- After a long period of research and practice, measures were taken to prevent casing damage of early stage development , to slow the DU 84 thermal recovery casing damage rate, to ensure the effective development of Du 84 super heavy oil steam stimulation and SAGD development implementation.

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