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Mechanism and prediction analysis of sustained casing pressure in "A" annulus of CO_2 injection well

Hongjun Zhu [a,*], Yuanhua Lin [a], Dezhi Zeng [b], Deping Zhang [c], Hao Chen [b], Wei Wang [b]

[a] State Key Laboratory of Oil and Gas Reservoir Geology and Exploitation (Southwest Petroleum University), Chengdu, Sichuan 610500, China
[b] CNPC Key Lab for Tubular Goods Engineering, Southwest Petroleum University, Chengdu, Sichuan 610500, China
[c] Jilin Oil Field Company, PetroChina, Songyuan, Jilin 138000, China

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ABSTRACT

High value of sustained casing pressure (SCP) threatens the wellbore essential safety and environmental protection seriously. Considering the special and complex characteristic of SCP in "A" annulus of CO_2 injection well, a prediction model of buildup of casing pressure has been proposed in this paper. Then finite difference method was used to solve the discrete equations in order to predict the SCP variation with time. The value is closely related to size and position of leak point, leakage rate, height of annular protective liquid, length of gas column at wellhead and the state of CO_2. The buildup of SCP in one well in Jilin Oilfield is obtained by this model, which is in good agreement with the actual result, verifying the reliability of coupled model and calculation method.

1. Introduction

After well completion, measuring pressure in all of the casing strings should be zero if the well is flowing at steady state conditions, and a small volume of fluid caused by thermal expansion effects has to be bled through a needle valve in order to decrease the casing pressure to atmospheric pressure (Bourgoyne et al., 1999). If the casing pressure builds up when the needle valve is closed, the casing generally exhibits sustained casing pressure (SCP). High casing pressure may induce blowout, explosion and other serious accidents, reducing the productive life of oil and gas wells and resulting in huge economic losses.

SCP in gas producing wells is very common, such as 11,498 casing strings in 8122 wells in the Gulf of Mexico (Bourgoyne et al., 1999). Thus, gas migration in gas producing well has been studied by some researchers (Somei, 1992; Xu and Wojtanowicz, 2001; Xu, 2002). Among them, Xu's work is the most detailed one. In Xu's (2002) dissertation, she had built a mathematical model of casing pressure in "B" or "C" annulus wellhead of gas producing well and had given the numerical solution. However, a well usually has several annuli. According to the location, the annulus from inside to outside can be named "A" annulus, "B" annulus, "C" annulus, and so forth (Anders et al., 2006). As shown in Fig. 1, "A" annulus is the annulus between the tube and production casing. "B" annulus is the annulus between production casing and adjacent intermediate casing. The rest can be obtained by analogy. The gas migration path in "A" annulus is not the same as that in "B" or "C" annulus. In "A" annulus, gas may flow through annular protective liquid and accumulate at the gas chamber in wellhead. While in "B" or "C" annulus, gas may sequentially flow through cement and mud column to reach the gas chamber. Moreover, annular protective liquid is water added by corrosion inhibitor, while mud is usually a non-Newtonian liquid–solid two-phase fluid. Therefore, Xu's model cannot be directly applied in "A" annulus.

Recently, with the spread of CO_2 enhanced oil recovery (Haynes and Alston, 1990; Hargrove, 2004; Keeling, 1984; Tanner and Baxley, 1992), SCP in CO_2 injection well has become a salient problem, which has been found in all oil fields using CO_2-EOR in China. Especially, SCP in "A" annulus is the most serious challenge. In Jilin Oilfield, the maximum casing pressure in "A" annulus of CO_2 injection well is up to 17.5 MPa. In some injection wells, obvious casing pressure appears just one week after operating, and the pressure builds up quickly and approaches the tubing pressure after pressure relief. Therefore, it is urgent to understand the mechanism of SCP in "A" annulus of CO_2 injection well and predict the value of SCP. However, there are few reports about the mechanism of SCP and gas migration in CO_2 injection well, which is a highly complex problem due to its own special characteristics such as acidic property and supercritical state of CO_2. In addition, unlike gas producing well, fluid flows in the opposite direction in tubing of gas injection well. It is another distinctiveness of SCP in CO_2 injection well.

The work presented here, therefore, focuses on the mechanism and prediction analysis of SCP in "A" annulus of CO_2 injection

* Corresponding author. Tel.: +86 28 83032206.
E-mail address: ticky863@126.com (H. Zhu).

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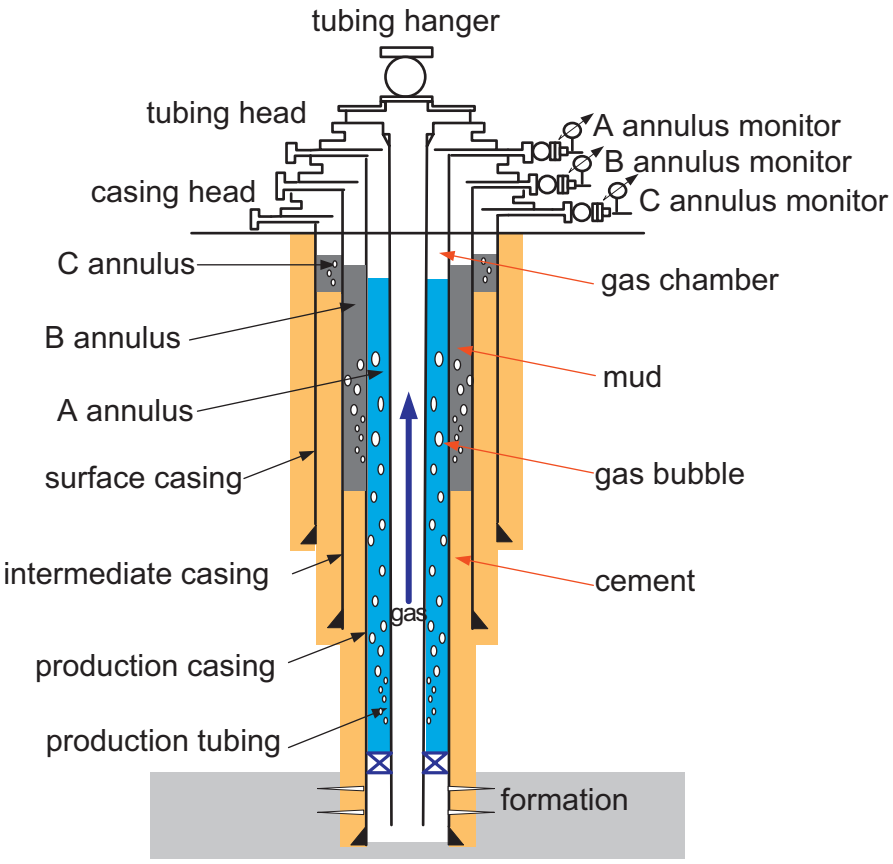

Fig. 1. Annulus schematic drawing of gas producing well.

well, which may provide some reference for the following security evaluation and solution measures of SCP.

2. Field data analysis

SCP is a universal problem in CO_2 injection wells in Jilin Oilfield, which is the first Oilfield using CO_2-EOR in China. The field data are "A" annulus casing pressure records provided by various operators from six injection wells in one block in Jilin Oilfield as shown in Fig. 2. According to Xu's classification (Xu and Wojtanowicz, 2001; Xu, 2002), three typical response patterns could be concluded from the field data, which are incomplete casing pressure buildup pattern, S-shape casing pressure buildup pattern and stable casing pressure pattern.

Incomplete casing pressure buildup pattern is noted when casing pressure increase at early time is relatively low and no pressure stabilization is apparent in the recording time, such as A well and B well. Comparatively, the rate of pressure rise in A well is faster than that in B well. There are two possible reasons. One is that A well is in a quick buildup period soon after pressure relief. The other is that there is a more serious leakage in A well.

Pressure stabilization occurs at an early time due to stable gas channeling. If the diameters of leaks in tubing or casing expand or new leaks arise, the casing pressure would increase gradually and finally stabilize at a new level. It is the S-shape casing pressure buildup pattern, which takes place in C well and D well. The amplitude of leaks expansion or increment of leaks in D well is greater than that in C well.

If the casing pressure has reached stabilization before recording, stable casing pressure pattern would be observed in the recording time, as seen in E well and F well. Disabled tubing hanger of F well was replaced with a new one during the recording time, so the curve has two sections. However, the later pressure stabilization indicates that leaks still exist in the well after the replacement of tubing hanger.

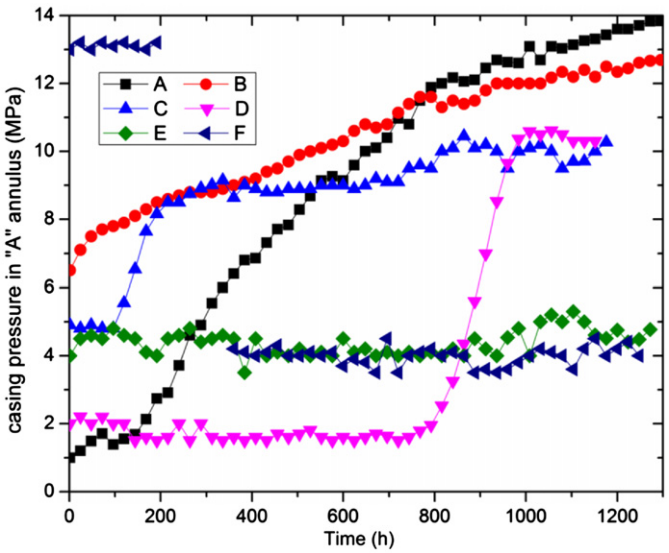

Fig. 2. Casing pressure records of six CO_2 injection wells.

3. Mechanism of SCP

In CO_2 injection well, tubing, casing, packer and even cement may be corroded by sour CO_2 under appropriate humidity and