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Environmentally assisted cracking performance research on casing for sour gas wells

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ABSTRACT

Flowage in rock salt may induce extrusion deformation on casing pipes; this hinders performance in the production process in injection wells and also challenges security in oilfields. The typical treatment for this problem is to grind or expand the deformed sections of the casing, which itself may cause additional damage (cold hardening) in the casing. Cold hardening may degrade the performance of casing materials, especially when the materials are exposed to a high-sulfur environment. Since it is common for casing pipes materials exposure in the H_2S/CO_2 environment like Puguang gas field, the cracking sensitivity of C110 after cold hardening is very important.

To investigate the environmentally assisted cracking performance of C110, a series of tests were conducted, including the basic mechanical property test, the electrochemical corrosion test, the Double Cantilever Beam test (DCB), and the four-point bending test. The results indicate that cold hardening increases the yield strength, reduces the impact toughness, and degrades sulfur-resistance which greatly increases the potential risk to the integrity of the wellbore.

1. Introduction

In oil and gas fields, well safety is always a top priority. Casing extrusion deformation is a threat to well safety that begins during the production process. For example, earthquakes can lead to large-scale casing deformations (Yokobori et al., 2001). Although it is not fully understood how earthquakes affect the development of oil and gas fields across the world, extensive evidence procured from the oil and gas fields in areas such as the Ingushetia sector in the former Soviet Union (Ge and Chen, 2010), Daqing oil field in China (Liu, 1989), Wilmington oil field in USA (Roberts, 1953), Ekofisk field in the US (Yudovich et al., 1989), Kurau oil field in western Indonesia (Calosa et al., 2010), and others suggests a strong connection between casing deformation and earthquakes.

Experts such as Hongkui Ge (Ge and Chen, 2010), Kaisong Wu (Wu and Luo, 2009) and Junsheng Shi (Shi and Gu, 2009) believe this kind of high percentage casing deformation observed in the Puguang gas field in South China was related to the May 12th Wenchuan earthquake. Relevant data shows that casing deformation damage has been affected by differing extents in 20 of the 22 wells as of October 2008 (Ge and Chen, 2010). Extrusion deformation of casing sections is mainly distributed within the gypsum layer of the Lower Triassic Jialing Jiang formation (3900 m to 5200 m).

40-arm logging was performed on a well within the interval of 3900 to 5700 m on September 9, 2009. The logging data shown in Table 1 and Fig. 1 show that a serious deformation was detected from 4609 to 4639 m. The different colors in Fig. 1(a) illustrate the diameter change around the casing. The red part represents casing shrinkage, the blue part indicates casing extension, and the yellow part depicts the unchanged casing. In the diagram of the cross section of the casing (Fig. 1(b)), the black line shows the original shape of the casing while the red line shows the actual shape after casing deformation.

On December 19, 2009, the casing of the well was repaired successfully in a swaging operation. On January 10, 2010, a 40-arm caliper logging was carried out for the third time to investigate the details of the casing's inner diameter. Table 2 shows that no significant new deformation was observed in the three selected logging intervals. This further indicates the major influence of the Wenchuan Earthquake on the gypsum layer of the lower Triassic Jialing Jiang formation and the resulting casing damage caused by that influence.

Rolling reshaping technology and downhole hammer technology are

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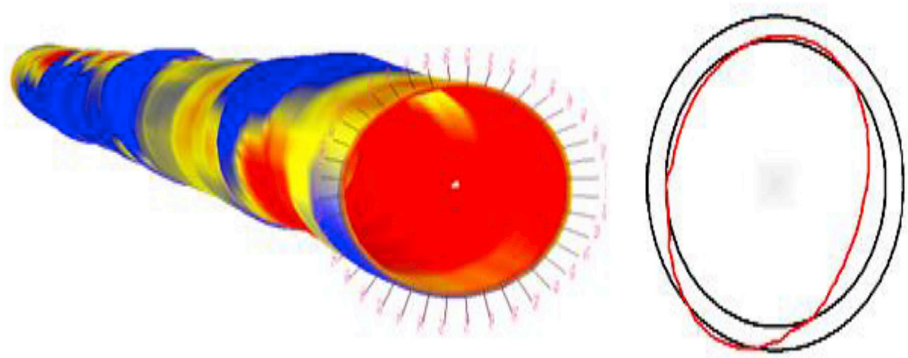
Table 1
Casing deformation of X well logged with 40-arm caliper for the second time (september 9th, 2009).

Deformation Section (m)	Length (m)	Casing ID (m)	Lithology	Logging Value with 40-arm Caliper					Conclusion
				Min. borehole diameter (mm)	Max. borehole diameter (mm)	Average borehole diameter (mm)	Min. borehole diameter change (mm)	Max. borehole diameter change (mm)	
4609–4639	30.0	152.5	Saliferous rock	119.99	189.68	152.65	−5.22	+5.03	Serious deformation
4729–4746	17.0		Saliferous rock	139.40	169.43	153.75	−2.13	+11.23	Serious deformation
4821–4861	40.0		Saliferous rock	143.89	168.60	154.38	−0.56	+3.00	Moderate deformation



(a) (b)

Fig. 1. Three-dimensional image and sectional view of 4609–4639m Section of X well suffering casing deformation.

Table 2
Casing deformation of X well logged with 40-arm caliper for the third time (january 10th, 2010).

Deformation Section (m)	Length (m)	Casing ID (mm)	Lithology	Logging Value with 40-arm Caliper					Conclusion
				Min. borehole diameter (mm)	Max. borehole diameter (mm)	Average borehole diameter (mm)	Min. borehole diameter change (mm)	Max. borehole diameter change (mm)	
4609–4639	30.0	152.5	Saliferous rock	121.07	185.20	152.82	+1.08	−4.48	Serious deformation
4729–4746	17.0		Saliferous rock	139.40	168.15	153.75	0	−1.28	Serious deformation
4821–4861	40.0		Saliferous rock	142.67	168.70	154.51	−1.22	0.10	Moderate deformation

applied to restore or expand the deformed sections of casing. The grinding and expanding process leads to secondary damage in the form of cold-hardening which may cause an inherent change in the casing material's characteristics. Environmentally assisted cracking is the most hazardous situation that the degradation of casing material can cause (Rusch et al., 2004). However, the effect of that degradation on the further strength and performance of casing material in the most complex wellbore environment has seldom reported in previous studies. Based on the industry-oriented idea, the environmental, situational, and material factors of a gas well in Puguang were selected for this study.

In Puguang gas field, C110 casing (Φ 177.8 mm) is widely used in structures located between 5500 and 6000 m below ground. The average content of H_2S and CO_2 is 14% and 8% in natural gas produced in Puguang with high temperature and high pressure, respectively.

In the original design chosen for this site, we adopted an integrated string system, using high nickel-based alloy production tubing and a permanent packer for acid production. The packer was to be located in the alloy casing annular section to prevent the C110 casing from corroding during the production process. However, during the construction of the well, the packer in Puguang XX well was set in advance; this caused the completion string fail to reach the designated position, as shown in Fig. 2. As a result of the unsuccessful isolation of the C110 casing, two sections of C110 casing in XX well are potentially hazardous.

The first section is the deformed casing section stretching from 5500 to 6000 m (section 1, seen in Fig. 2). This section of the casing was exposed in the cold-hardening process. Furthermore, because of the permanent packer set ahead, it is not clear whether or not the oil-swelling packer can properly work, which indicates that the acid gas (H_2S and CO_2) may leak into the A annulus (seen in Fig. 3). Therefore, this section of casing is facing potential stress corrosion cracking or stress cracking.

Another dangerous casing section is section 2 shown in Fig. 2 which is directly exposed in the H_2S and CO_2 environment. Although the casing section was not damaged by the cold hardening process, the potential for stress corrosion cracking still exists. From Fig. 2 and Fig. 3, it is clear that